
EX BIBLIOTECÂ
D. A. de VLLOA

ROHAULT's
SYSTEM
OF
Natural Philoſophy,

ILLUSTRATED WITH
Dr. *Samuel Clarke's* NOTES

Taken moſtly out of
Sr. *Iſaac Newton's* Philoſophy.

With ADDITIONS.

VOL. I.

Done into *Engliſh*
By JOHN CLARKE, D. D. *Dean of* Sarum.

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THE

Tranſlator's Preface.

THE ſeveral Editions which this Treatiſe has paſs'd through, both in *French* and *Latin*, are a ſufficient Teſtimony how acceptable and uſeful it has been to the World, and a juſt Apology for my tranſlating it into *Engliſh*. I ſhall not therefore trouble the Reader with any particular Account either of the Excellency of the Subject, the Abilities of the Author, or the Method he has proceeded in, but refer them all to be judged of by the Book it ſelf: Only as to the Notes the Reader is deſired to take Notice, that therein is a full Anſwer to ſuch Objections made againſt the Author as ſeem not to have any juſt Foundation, and a great many Things in Natural Philoſophy, which have been ſince found out by the Pains and Induſtry of later Philoſophers, are here ſelected from the beſt Writers; and there are

alſo ſeveral Things added out of the Obſervations of the ancient Writers of Natural Philoſophy and Natural Hiſtory, where they ſeemed further to explain and illuſtrate Matters. In all which, to avoid Repetition, Gratitude demands that the Reader ſhould know that there are a great many Things owing to the learned and induſtrious Dr. *Laughton*, and to the Reverend Mr. *Morgan*. The former of which communicated a great many Things diſperſed throughout the whole Book, and corrected Abundance of Errours: And ſix whole Diſſertations are owing to the latter, *viz.* Thoſe concerning *the Laws of communicating Motion in elaſtick Bodies*; *The Explication of the Forces of the mechanick Powers*, which are contained in this firſt Part: and thoſe concerning *the Celerity with which heavy Bodies deſcend*; *the Motion of Projectiles*; *the Motion of Pendulums*; *and that concerning the Rainbow*; which are contained in the following Parts.

THE fourth Part of this Work is but ſhort, and not very perfect; wherefore it is thought more adviſeable to refer the Reader to later Writers of Anatomy who have handled that Subject clearly and fully, than to tranſcribe ſo many Particulars. I hope the Whole will be agreeable and acceptable.

THE

Author's *PREFACE.*

THE Treatifes of Natural Philofophy which have hitherto been publifhed, being pretty much alike, both as to the Matter of them, and the Manner of handling them; It is eafy for me to forefee, that amongft thofe who read This, there will be a great many who will be at firft furprifed at the great Difference there is between this Treatife and others. To prevent therefore in fome Meafure this Surprize, and to give what Satisfaction I can in this Matter, I think my felf obliged to give an Account of the Obfervations which I have made upon the Philofophy of the Ancients, and of the Method which I have taken in this Work.

IN reflecting upon the different Effects of Time, I have long fince obferved, how favourable it is to fome Things, which it is continually advancing to Perfection, and how pernicious it is to others, fo as to ftrip them of thofe Beauties and Graces

which they had at their firſt Riſe; and I always concluded that Arts and Sciences cannot be of the Number of theſe latter, but that Time is ſo far from being prejudicial to them, that on the other Hand it is very advantagious. For as a great Number of Perſons who cultivate the ſame Art or Science for ſeveral ſucceeding Ages, add their own Induſtry, and their new Light to the ancient Diſcoveries of thoſe who went before them, it is impoſſible but that ſuch an Art or Science muſt receive great Improvement, and arrive nearer and nearer to its utmoſt Perfection.

AND thus I ſaw that Mathematicks did really increaſe by little and little in this Manner; as it is eaſy for any one to be convinced of, who conſiders only the vaſt Progreſs that hath been made by the great Genius's of our Time, who have excelled all others in this Particular, and ſurmounted ſuch Difficulties as the moſt Learned in former Ages confeſſed they were not able to ſolve. I ſaw alſo that moſt Arts were perfected by Time; Workmen every Day finding out a Multitude of curious Inventions, which are not ſo much eſteemed as they deſerve, becauſe they are very common, and we do not enough take Notice of them. Though amongſt thoſe Engines which are employed in making Things of common Uſe, there is *One* that has been lately invented, which has in it ſo much Contrivance, that this ſingle Thing deſerves to be more

more admired than all the Inventions of Antiquity.

BUT when I came to confider Philofophy, particularly Natural Philofophy, I was very much furprized to fee it fo barren as not to have produced any Fruit; in fo much that twenty Ages have paffed, without any new Difcovery made in it.

HOWEVER, I could not perfuade my felf, that the Study of Natural Things was neglected, becaufe it was thought to be of no Ufe; for Health has always been efteemed one of the chief Bleffings of Life, and no one can be ignorant, that Phyfick, the fole End of which is to maintain and reftore Health, is built upon Natural Philofophy.

NOR could I ever perfuade my felf, that thofe who improved this Science were lefs ingenious, than common Artifts: For we find by Experience that in Families where there are a great many Children, when they come to make choice of their Profeffions, thofe of them which have the quickeft Genius, are appointed for Study, or voluntarily incline themfelves to it; and thofe only whofe Underftanding is not fo good, apply themfelves to the mechanical Arts, and are contented with their Lot.

HEREUPON I fufpected, that perhaps the Knowledge of Natural Things was above the Reach of humane Underftanding, fo that it was in vain to labour to attain that which is beyond our Capacity: but when I

confidered the furprizing Things done by fome Philofophers of our own Age, who within forty or fifty Years have found out Things which were looked upon as moft difficult, and which fome have doubted, whether ever they could be found out at all; I immediately caft off this Sufpicion.

So that I was forced to conclude, that the *Manner* of philofophizing, was the Thing that had hitherto been miftaken, and that the Errors *therein* which have been introduced, being fuch as no Body had any Hopes of finding out a Remedy equal to, were a certain Bar to hinder the Approaches towards Truth. I fet my felf then to enquire wherein the *Manner* of their treating Philofophy was defective; and after having examined with the greateft Diligence poffible, what the Method has been from the Schools of the *Athenians* down to this very Time; there feemed to me to be four Things blameable in this Matter.

Firft, THE too great Authority that hath always been given to the Ancients in the Schools: For befides that this prodigious Difference which is put between them and the Moderns, is without the leaft Foundation; (for Reafon is to be found in every Place and every Age;) it is certain that fuch a blind Submiffion to the Opinions of Antiquity, is the Caufe why Perfons of the greateft Genius, (receiving fuch Opinions for true without confidering them, when perhaps they may be falfe,) have not an Oppor-

portunity of knowing the contrary Opinions, nor confequently of finding out all thofe other Truths that depend upon thofe which fo fatal a Prejudice has hindred them from feeing. And further, this ftrong Perfuafion of our being fo much inferiour to the Ancients, caufes in us a Kind of Sluggifhnefs and Diffidence, which hinders us from attempting to enquire into any Thing at all. We imagine that Reafon is limited at the Place where they ftopped, and that all is done that can be done humanely fpeaking, if we go as far as they went. Thus the greateft Genius's contenting themfelves with going over the Reafonings of the Ancients, don't exercife their own Reafon at all; and though they be never fo capable of finding out any Thing themfelves, they contribute no more to the advancing Natural Philofophy, than if they had not meddled with it at all.

I fay nothing particular of that Veneration which hath been paid to *Ariftotle*, though fometimes it has rifen to fuch an Excefs; that to alledge that he faid fuch a Thing, was fufficient to make any One not only to doubt of what his Reafon convinced him, but even to condemn it. I fhall only make this Obfervation; that the Imagination which a great many have had, that He knew all that could be known; and that all Science was contained in his Books, hath caufed the greateft Part of the beft Philofophers fince to apply themfelves in vain to

read his Works, to find out in them what was not there, and what they might perhaps otherwife have found out by their own Ingenuity. But if there have been fome who, not being quite fo zealous as others, did not hope to reap fo very much Fruit from reading him; yet it always happened that the Defire of recommending themfelves by explaining thofe Places which he left obfcure (on purpofe, as fome think, or elfe for want of better Light) hath made them employ their whole Strength of Mind, and all their leifure Time, to very little Purpofe, in writing Comments upon his Philofophy, without promoting the Science at all: For thofe who have undertook to explain *Ariftotle*; have underftood him fo differently, that there are an infinite Number of Places which all the Schools are divided about; And if there be fome few in which they have agreed, it is becaufe the Notions contained in them were fo common, that very few Perfons were ignorant of them. So that they took more Pains to ftudy *Ariftotle* than they did to ftudy Nature, which perhaps is not near fo myfterious as He. There are a Multitude of Things which Nature plainly declares to thofe who apply their Mind thereto. But alas, this is not the Cuftom, we had rather hearken to *Ariftotle* and the Ancients; and this is the Reafon why we make fo little Progrefs.

ANOTHER Thing which hinders the Progrefs of Natural Philofophy, is the Treat-

ing thereof in a Manner too metaphyfical; and the Difputing about Queftions fo abftract and general, that though all Philofophers were agreed in their Notions of them, yet they would not help to explain the leaft particular Effect in Nature; whereas every ufeful Science ought to defcend immediately to Particulars. For Inftance, what good do thofe long and nice Difputes do, *about the Divifibility of Matter?* For though it could not be accurately determined, whether it be infinitely divifible or no; it would be fufficient to know, that it can be divided into Parts fmall enough to ferve for all Purpofes that can be.

IT is very ufeful, without doubt, to find out the Nature of Motion in general. And it may not be very improper to examine a little whether it be well or ill defined thus, *The Act of a Being in Power, fo far forth as it is in Power.* But we fhould not fpend too much Time in determining this, and fuch like Queftions; I fhould rather think, that after having confidered a little the true Nature of Motion in general, we fhould particularly and diftinctly examine all the Properties of it, fo that what we affirm concerning it, may be applied to fome Ufe; In a word, I think we fhould carefully enquire into the Caufe why Matter produces fuch a particular Effect rather than any other, and not accuftom ourfelves to fay that it is the Effect of a certain *Quality*; for from hence it is that we are led to give

Words

Words inſtead of Reaſons, and hence ariſes that ſenſeleſs Vanity of thinking that we know more than others, becauſe we know Words which the common People don't know, and which indeed have no determinate Meaning. To ſay the Truth; it ſhows a mean Spirit, and one that is ſoon ſatisfied; to believe that we know more of Nature than other Men, becauſe we have learn'd that there are occult Qualities, and can give a General Anſwer to all Queſtions propoſed to us concerning the different Effects of Nature. For what Difference is there in the Anſwer of a Plowman and a Philoſopher, if they are both asked, whence is it, for Inſtance, that the Loadſtone attracts the Iron, and the one anſwers, that he does not know the Reaſon of it, and the other ſays, it is done by ſome Vertue or occult Quality? Is not this in plain *Engliſh*, to ſay the ſame Thing in different Words? and is it not evident, that all the Difference there is betwixt them is only this, that the one is ſo honeſt as to confeſs his Ignorance, and the other has the Vanity to endeavour to conceal his?

A third Defect which I have found in the Method of Philoſophers, is, that ſome of them are wholly for Reaſoning, and depend ſo much upon the Strength of their Arguments (eſpecially if they be borrowed from the Ancients) that they judge it ſuperfluous to make any Experiments. Others on the contrary, quite tired with ſuch tedious Arguments,

guments, the greateſt Part of which are not concluſive, or are nothing to the Purpoſe, think every Thing ought to be reduced to Experiment, and that there ſhould be no Reaſoning at all. But both theſe Extremes do equally hinder the Progreſs of Natural Philoſophy. For they who fall into the firſt of theſe Errors, hinder themſelves of the beſt Means of finding out new Diſcoveries, and of confirming their own Arguments likewiſe; And they who fall into the ſecond, by depriving themſelves of the Liberty of drawing Concluſions, hinder the Knowledge of a large Train of Truths, which may many Times be deduced from one ſingle Experiment. Wherefore it cannot but be very advantagious to mix Experiments and Arguments together. For Reaſoning perpetually, and upon ſuch general Things only as are ordinarily argued about, without deſcending to Particulars, is by no Means the Way to attain any very extenſive or very certain Knowledge: Thus we ſee the ſame Things continually bandyed about, and no new Diſcoveries made; nay, we are not very ſure of the old ones, as general as they are. We ſee alſo that they who confide moſt in thoſe Arguments which they believe to be *Ariſtotle's*, are in perpetual Diſpute, and that they contend for Opinions which are directly contrary to one another, without being able to convince thoſe of the other Side by their Arguments. And this plainly ſhows how little Certain-

ty or Evidence there is in their bare Reasoning.

EXPERIMENTS therefore are necessary to establish Natural Philosophy; and this was a Thing which *Aristotle* was so fully convinced of, that the Reason why he thought that very young Persons should not apply themselves to the Study of Natural Philosophy, was, because at that Age they are so little acquainted with Things, as to be unable to have made many Experiments; and on the other Hand he was of Opinion, that they were then most capable of receiving Mathematicks, because this Science consists of meer Reasoning, of which the Mind of Man is naturally capable, and does not at all depend upon Experiments.

BUT on the contrary to reject entirely all Reasoning, in order to do nothing but make Experiments, is to run into another Extremity much more prejudicial than the former. For this is wholly to discard Reason, and yield all up to Sense, and to contract our Knowledge into a very narrow Compass; for by Experiments we can come to the Knowledge of gross and sensible Things only. Wherefore if we would proceed rightly in our Enquiries into natural Things, we must of Necessity mix these two Means of Knowledge together, and join Reason with Experiments.

AND that we may the better see the good Effects of these two when joined together, and the Use that may be made of them,

to the Advantage of Natural Philofophy, we may obferve that there are three Sorts of Experiments. The firft is, to fpeak properly, only the mere fimple ufing our Senfes; as when accidentally and without Defign, cafting our Eyes upon the Things around us, we cannot help taking Notice of them, without thinking of applying what we fee to any Ufe. The fecond Sort is, when we deliberately and defignedly make Tryal of any Thing, without knowing or forefeeing what will come to pafs; As when, after the Manner of Chymifts, we make Choice of firft one Subject and then another, and make all the Tryals we can think of upon each of them, and carefully remember what we have at any Time found to fucceed, and the Manner in which we arrived at any certain Effect, in Order to apply the fame Means another Time to produce the fame Effect. We alfo make Experiments in this fecond Way, when we go amongft different Sorts of Workmen in Order to find out the Myfteries of their Arts, as Glafsmakers, Enamellers, Dyers, Goldfmiths, and fuch as work different Sorts of Metals, and to obferve how they prepare their Materials, and how every one of them afterwards work upon thofe which belong to them. Laftly, The third Sort of Experiments are thofe which are made in Confequence of fome *Reafoning* in order to difcover whether *it* was juft or not. As when after having confidered the

ordinary Effects of any particular Subject, and formed a true Idea of the *Nature* of it, that is, *of That in it which makes it capable of producing those Effects*; we come to know by our Reasoning, that if what we believe concerning the *Nature* of it be true, it must necessarily be, that by disposing it after a certain Manner, a new Effect will be produced, which we did not before think of; and in Order to see if this Reasoning holds good, we dispose the Subject in such a manner as we believe it ought to be disposed in Order to produce such an Effect.

NOW it is very evident that this third Sort of Experiments is of peculiar Use to Philosophers, because it discovers to them the Truth or Falsity of the Opinions which they have conceived. And as to the two foregoing ones, though they be not altogether so excellent, yet they ought not to be wholly rejected as of no Use to Natural Philosophers: For besides that their Knowledge is continually enlarged by them, they are also the Occasion of making the first Conjectures concerning the Nature of those Subjects which Natural Philosophers are conversant about; and preserve them from some false Notions they might otherwise perhaps have entertained. Thus, for Instance, we might have concluded in general, that *Cold contracts and condenses every Thing*, if we had not discovered by Chance or

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otherwise, that there are Things which are dilated by Cold.

THE fourth Defect that I observed in the Method of Philosophers, is the neglecting Mathematicks to that Degree, that the very first Elements thereof are not so much as taught in their Schools. And yet, which I very much wonder at, in the Division which they make of a Body of Philosophy, they never fail to make Mathematicks one Part of it.

NOW this Part of Philosophy is perhaps the most useful of all others, at least it is capable of being apply'd more Ways than all the others: For besides that Mathematicks teach us a very great Number of Truths which may be of great Use to those who know how to apply them: They have this further very considerable Advantage, that by exercising the Mind in a Multitude of Demonstrations, they form it by Degrees and accustom it to discern Truth from Falsehood infinitely better, than all the Precepts of Logick without Use can do. And thus they who study Mathematicks find themselves perpetually convinced by such Arguments as it is impossible to resist, and learn insensibly to know Truth and to yield to Reason; insomuch that if instead of neglecting them, as is usually done; it were an established Custom, to make Children apply themselves to this Science at first, and to improve them in these Studies as much as we do in others; it would be of vast Use to hinder them from contracting that invincible Obstinacy

in their Opinions which we fee in the greateft Part of thofe who have compleated their Courfe of Philofophy; who probably would not have fallen into fo pernicious a Temper of Mind, if they had been accuftomed to, and familiar with convincing Truths; and not feen thofe who maintain in publick any Doctrine whatever, continually triumph over thofe who endeavour to fupport the contrary; fo that all Things feem to them only mere Probabilities. They do not look upon ftudying as a Means to difcover new Truths, but only as a Piece of Wit to exercife themfelves in, the only End of which is fo to confound Truth with Falfehood by Means of fome fubtle Diftinctions, that the one or the other may be equally maintained, without ever being compelled by any Reafons to yield, let the Opinion they defend be never fo extravagant. And indeed this is the Event of all publick Difputes, where very often Opinions directly contrary to each other, are by Turns propofed from the fame Chair, and equally triumphed in, without making Matters at all clear, or eftablifhing any Truth thereby.

BUT the great Advantage that natural Philofophers have from Mathematicks in particular, is, that they are thereby accuftomed to the viewing of Figures, and enabled to underftand the different Properties of them. I know it is here objected by fome, that we ought not to ftop at Figures, becaufe they are not *active*. But though

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they are not *active* in themſelves, yet it is certain notwithſtanding that their *Differences* make Bodies, which we put into Action, capable of certain Effects, which otherwiſe they could not have produced. Thus a Knife by having an Edge ſet upon it becomes capable of cutting, which before it was not; and Workmens Tools, by their different Figures, are fitted to produce thoſe different Works which are made by the Help of them. And if the Figures of Bodies which come under our Senſes are ſo neceſſary to the Effects which they produce, it is reaſonable to think that the moſt imperceptible Parts of Matter, ſeeing they have every one a certain Figure, are alſo capable of producing certain Effects in Proportion to their Bigneſs, like thoſe which we ſee produced by the groſſeſt Bodies.

BUT not to enter too far into Particulars concerning the great Uſe of Mathematicks, Is it not enough to put us upon applying ourſelves more to them than we have hitherto done, to conſider that 'tis by their Means that the modern Philoſophers have diſcovered all that is excellent and peculiar in natural Philoſophy? And alſo that it is by the Help of Mathematicks, that the moſt celebrated Artiſts in every Age have made all thoſe noble Diſcoveries, the Uſe of which is ſo advantagious to us at this very Time, and which make all the Variety of Arts and all the Conveniences of Life. It may be ſome may think on the contrary,

that these very Artists, the greatest Part of whom it is very probable have not much applied themselves to this Science, will justifie it, that it is not so necessary as I would persuade them. But here there are two Things to be considered: First, that as there is a natural Logick in all Men, so is there also natural Mathematicks, which according as their Genius's are disposed, make them more or less capable of Invention. Secondly, That if their Genius alone, conducted only by natural Light, will carry them so far, we cannot but hope greater Things from the same Genius if the Study of Mathematicks be added to its natural Light, than if that Study be neglected. And indeed all the Propositions in Mathematicks, are only so many Truths, which those, who apply themselves to them, come to the Knowledge of by good Sense. And they who find themselves naturally disposed to it, do very ill to neglect what others have before discovered: For it is the most certain Way of finding out any Thing new, to know all that has been before found out by others, and the Manner how it was found out.

HOWEVER, I don't put them upon the Rank of Inventors who have met with something by Chance which they did not search after: As was the Case of that Workman who by cooling on a sudden in the Water a Piece of Steel which he had heated red hot, found it in a Moment very much harder than it was before: It was

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without doubt a very lucky Thing to find out this Way of tempering Steel; but the Workman who had the good Fortune to hit upon it, does not deferve the Name or Title of an Inventor; as a great many others do who are not beholden to Chance for the Glory of their Inventions: As for Inftance, the Perfon who firft invented a Fire-lock to a Gun; for it is certain that this latter had the whole Engine in his Head, if I may fo fpeak, before he made the leaft Part of it, whereas the other found out the Way of tempering Steel, by hitting upon a Thing, as was before faid, by Chance, which he did not fearch after.

Laftly, THAT Mathematicks are of very great Ufe in the other Parts of Philofophy, we need no other Teftimony than that of the moft celebrated ancient Philofophers, who not only fpeak honourably of them in their Writings, but do alfo make ufe of them themfelves. It is fufficiently known, that *Plato* caufed it to be written over his School Door, *That none but Geometricians fhould enter in there.* And they who have taken the Pains to read over the Works of *Ariftotle*, have taken Notice of the feveral Applications he has made of Mathematicks in many Places; fo that they who do not underftand the Elements at leaft, have no great Reafon to boaft of their being able to underftand the Writings of this Philofopher.

THE more I confider thefe four Defects in the Method of Philofophers, the more I find it impoffible to come to the Knowledge of philofophical Truths, without correcting them. And this does not appear to me to be very difficult; for though I had made fome Proficiency in Mathematicks, and accuftomed my felf to follow Reafon rather than Authority, yet I did not find my felf fuch a Lover of my own Reafonings, as to neglect Experiments, nor fo bent upon Experiments, as not to fuffer my Reafon to go beyond what they difcovered.

BUT though this was fufficient to put me upon improving natural Philofophy, and to make me hope that I might be able in fome Meafure to help forward the Progrefs of this Science; yet I obferved a fifth Defect, not in the *Method* of thofe who ftudy Philofophy, but in *that* of a great many who read their Works; which made me think, that to publifh any Thing upon natural Philofophy, was fo far from being any Advantage, that it was but too much to expofe one's felf. For that Averfion which is ufual againft fuch Perfons, and that difagreeable Manner in which thofe who are uncapable of finding out any Thing themfelves, receive the Writings of fuch as attempt to exceed what is common, often hazard the Reputation of the Author. For fcarce can a Philofopher prefent the Publick with any Fruits of his Studies, but fome unknown Perfon who has a Mind to fignalize him-

ſelf, attacks them before he underſtands them. And hence come thoſe trifling Diſcourſes or Diſſertations, for the moſt Part anonymous ones, which never fail immediately to appear, wherein are ſeldom any Thing elſe but Reproaches and very low Jeſts; and not being able to overthrow Truths that are ſo firmly eſtabliſhed; they try to turn them into Ridicule, by ſhowing that they are contrary to ſome ancient Maxim or popular Error, which tickle the Ears of half-witted People, who are accuſtomed to take Things without any Proof: And that which is very remarkable here, is, that theſe Writers for the moſt Part attack the Works of others only becauſe they think them contrary to *Ariſtotle*; and yet becauſe they have read nothing of this Philoſopher but only thoſe Citations which they found in their philoſophical Lectures, it very often happens that the Thing which they thus attempt to confute, is what *Ariſtotle* himſelf has ſaid in expreſs Terms. We may ſafely affirm, that the Ancients did more Juſtice to Men's Labours, and without doubt it was in a good Meaſure owing to this, that Philoſophy made ſome Progreſs in the firſt Ages of it; ſo far were they from ſuffering thoſe who had made any new Diſcoveries, to be cried down at a Venture and without any Reaſon; every Body knows that there were publick Rewards appointed for ſuch; even to have ſometimes Statues erected to them; ſo firmly were they perſuaded in

thofe Times that Honour contributed moft to the Invention of Arts.

It is true indeed, that this Maxim feems to be revived and re-eftablifhed in our Age. Yet though Princes have by their Authority approved and favoured Arts and Sciences, the long Stiffnefs which they who ftudied natural Philofophy have in fo many Ages contracted, have fo accuftomed them to reft fatisfied with what they received from their Predeceffors, that the very propofing any new Thing, is enough to render both the Thing and him that propofes it odious. Now to take away the Foundation or rather the Pretence of this Averfion, fuch Perfons ought to know, that this Reproach of Novelty is generally a great Deceit: For if a Thing be true, it cannot be new, becaufe nothing is fo ancient as Truth, and it is the Difcovery of the oppofite Errour only that can be faid to be new. For Want of rightly diftinguifhing thefe two Things, we often fee fome Perfons crying out that we overthrow the Order of Nature, when we only overthrow a falfe Opinion which they were prejudiced in. But though fuch Sort of Perfons have not much Reafon on their Side, yet the Credit and Authority which they may have over others, is the Caufe of their Exclamations always making an Impreffion upon the Minds of a great many; and this muft ever be difagreeable to thofe who have no other De-

fign,

ſign, but to contribute to the Publick Good.

WHAT a Vexation muſt it be to Dr. *Harvey*, for Inſtance, to ſee all his Life long, how ill the Diſcovery he had made of the Circulation of the Blood, was received; the Motion of which was quite different from what the Ancients thought? Surely we cannot ſhow too great an Acknowledgment to a Man who had undeceived the World of an ancient Errour, and by the Truth which he eſtabliſhed, made us ſee as clear as the Day, that almoſt all the Theory of the Phyſick of the Ancients was falſe. But how many Enemies has this Doctrine got him inſtead of Thanks? I ſolemnly declare therefore, that upon ſeeing what Liberty is taken to oppoſe the beſt Things, becauſe the Misfortune of Mens having always been ignorant of them, made them to be thought new; I laid aſide the Thoughts of ever entertaining the Publick with any Thing of my own, or what I learned from the Works of ſome modern Writers. But thus much I thought at leaſt, that it was not impoſſible to advance a little further than is generally done in the Knowledge of Natural Things, if I carefully avoided falling into any of thoſe Defects which I obſerved in the Method this Study was in at preſent. And indeed having ſpent ſome Years in reading the Ancients and Moderns, but with a firm Reſolution not to follow them any further than I could ſee the Rea-

fons of each of them; it appeared to me that my Defign was not entirely fruftrated. But while I was thus inftructing my felf by reading Books, and converfing with learned Men, and thofe that were excellent in any Art, I never laid afide the Ufe of my Reafon, but confidered the feveral Subjects, and endeavoured always to ground my Reafons upon mathematical Truths, and fure Experiments. And fo good Succefs had I in carrying on my Defign, that a great many of my Friends, whofe Abilities all the World, I faw, had a great Value for, advifed me to communicate it to others by publick Conferences, or at leaft by private Converfation. I muft fay, that it was very difficult to perfuade my felf to this, becaufe I am diftruftful of my felf, and do not think my felf Oratour good enough to undertake to plead the Caufe of Truth thus publickly. However I fuffered my felf to be over-ruled; and though I was fenfible I wanted a great many Talents, yet I fubmitted to my Friends, who affured me, that if the Things were plainly propofed, and in a mathematical Way, they would be acceptable at leaft to the beft Judges. And indeed their Advice fucceeded: For thefe Conferences were not only agreeable, but it was wifhed that the Subjects had been put down in Writing. And by confenting to this Opinion of my Friends, I perceived that I had infenfibly wrote a Book; and becaufe there were fo many Copies of it about, that it was become,

come, as it were, publick, and a great many Faults ſlipp'd in, I reſolved to review it more exactly, in Order to perfect it as much as I could. They who read it over, will eaſily ſee, that I have overlooked nothing that is good in the Ancients.

I have taken all the general Notions from *Ariſtotle*, either for the eſtabliſhing the Principles of natural Things, or the chief Properties of them: And I have rejected *a Vacuum* and *Atoms, or Epicurus's indiviſible Particles*, which I think are Things contrary to what is firmly eſtabliſhed by *Ariſtotle*; and I have learnt of him to conſider with the greateſt poſſible Care the different Bigneſſes, Figures, and Motions of the inſenſible Parts of which ſenſible Things are compoſed. And this I was the readier to do, becauſe all theſe Things have a neceſſary Connexion with, and Relation to *the Diviſibility of Matter*, which I acknowledge with *Ariſtotle*, who hardly reſolves any particular Queſtion, without conſidering the Bigneſs, Figure, and Motion of the Parts of Bodies, and the Pores which are between them. But that which moſt of all determined me to this Conſideration, was, that though there ſeems to me to be a juſt Ground to doubt of the Truth of ſome *Qualities* and *Powers* commonly aſcribed to ſome Bodies, yet I do not think that there is the ſame Reaſon to doubt of their being compoſed of *inſenſible Parts*, or that

that I can be deceived in affirming that all theſe Parts have their particular Figure and Bigneſs.

BESIDES thoſe Aſſiſtances which I had from the Ancients, I have alſo collected a great many other Truths, from the moſt eminent modern Philoſophers, whoſe Names you may find in their Places. But the Perſon whom I have moſt of all made Uſe of in this Work, and whoſe Name I have not mentioned at all, to avoid perpetual Repetition, is the famous *Cartes*; whoſe Merit, by which he becomes more and more known to all the Nations in *Europe*, as he has long been to many of the principal States, will draw a Confeſſion from the whole World, that *France* is at leaſt as happy in producing and educating great Men in all Sorts of Profeſſions, as ancient *Greece* was.

I have divided this Work into four Parts. The firſt treats of natural Bodies in general, and their principal Properties, ſuch as *Diviſibility, Motion and Reſt, of Elements, and of ſenſible Qualities*, and I have particularly infiſted upon explaining thoſe which relate to *Seeing*. And I flatter my ſelf that upon this ſingle Subject I have collected more Truths into eight or nine Chapters than are contained in ſeveral large Volumes which treat of Opticks, Dioptricks and Catropticks after the Manner of the Ancients.

THE ſecond, treats of *the Syſtem of the World, or of Coſmography*, which I thought might

might prove more useful than the general Questions that are usually proposed in the common Books of natural Philosophy, which are as it were Commentaries upon *Aristotle's* Books *concerning the World.* I have also treated of *the Nature of the Stars and their Influences.* And after having explained wherein *Gravity* and *Levity* consist (which I could not speak of in the first Part, not having premised what was necessary,) I conclude this Part with explaining the *Flux and Reflux of the Sea.*

THE third Part is taken up in explaining the Nature of the *Earth* and of *terrestrial Bodies,* that is, of the Bodies contained in it, or which surround it, as *Air, Water, Fire, Salts, Oyls, Metals, Minerals, and Meteors.*

Lastly, I have endeavoured in the fourth Part to comprise all that is hitherto, with any Certainty, known of the *Animal Body.*

ONE Thing perhaps will be observed in the Method I have taken, *viz.* that I have been pretty long and particular, in explaining, in the first Part of this Book, all the sensible Qualities, which Philosophers usually explain, and that but briefly, at the End of their Treatises of Philosophy, in which they comment upon these Books of *Aristotle's concerning the Soul.* The Reason of which is, because this teaches us to know ourselves, and because hereby we are seasonably freed from a popular Errour, and a Prejudice

which

which we have entertained from our Infancy, which I have known by Experience a great many never to have been able to get rid of, not even after they have gone through their whole Courfe of Lectures, but have brought back from the Schools thofe Habits they carried thither, *viz.* the afcribing their own Senfations to the Objects which caufe them, and the confidering thefe Senfations as Qualities in the Objects.

FURTHER, you will not find a great many Things in this whole Treatife contrary to *Ariftotle*; but you will find more than I could wifh that are contrary to moft of the Commentators upon him: And befides this, you will meet with a great many Things, which neither *Ariftotle* nor his Followers have treated of at all, which I have however judged more ufeful than many others which Philofophers have wholly imployed themfelves in. And in all this I did not think it very ill in me to depart from fome particular Notions, when I found that thefe Notions were difagreeable to Truth.

BUT what has very much abated thofe Scruples which I had about this Matter, is, that when I came to compare thofe Places in this Treatife which are contrary to *Ariftotle*, with the Writings of the publick Profeffors of his Philofophy, I could not find near fo many in my own Works as in the Works of others. And without enumerating the Particulars, it is eafy to be fatisfied herein,

if we do but confider, that there is fcarce any Queftion in Controverfy, but one half of them draw Conclufions directly contrary to the other half. Whence it follows, that we muft neceffarily find in the Writings of thofe who profefs to teach the Doctrines of *Ariftotle*, as many Places againft him as for him.

BUT though all the Philofophers did agree with each other and with *Ariftotle*, I don't fee that this Agreement of theirs ought to force me to be of their Opinions, nor that Philofophers can pretend that I am obliged to follow them, in what I am fully perfuaded and convinced they are in the wrong of. For fince it is the Cuftom with them to propofe the Matters which they treat of, in the Form of Queftions, this very doubting Manner of theirs fhows that there is a perfect Liberty of taking that Side which we think to be moft reafonable. In what Manner my good Intentions will be received Time will fhow. However, I am preparing a *Latin* Verfion for the Ufe of Foreigners, with whom I hope to meet with a favourable Reception.

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R O H A U L T's SYSTEM OF Natural Philoſophy.

PART. I.

CHAP. I.

The Meaning of the Word Phyſicks, and the Manner of treating ſuch a Subject.

THIS Word, *Phyſicks*, ſtrictly ſpeaking, and according to the Etymology of it, ſignifies no more than *Natural*; but we here uſe it to ſignify the Knowledge of natural Things, that is, that Knowledge which leads us to the Reaſons and Cauſes of every Effect which Nature produces. *1. The Meaning of the Word Phyſicks.*

2. But becauſe we muſt firſt ſtudy natural Philoſophy, before we can be certain whether there be any ſuch thing as *Phyſicks* or no; I ſhould not proceed in a proper Method, if I ſhould here undertake to reſolve this Difficulty. *2. That it is needleſs to ſtop at previous Queſtions.*

I ſhall not therefore at all inſiſt on this, nor any other Queſtions which are commonly called *previous* ones. We had better at firſt remain in ſome kind of Doubt about theſe ſort of Queſtions; but ſuch a Doubt only, as ought not in the leaſt to hinder us from uſing our utmoſt Endeavours to acquire this Knowledge, and to obtain the End propoſed, without neglecting any Thing, that may ſerve to illuſtrate the Truth, and explain the Effects of Nature.

3. That the Notions of the Antients may be injurious. 3. One Thing we ought particularly to take notice of, and that is, that all They who apply themſelves to the Study of *Natural Philoſophy*, are not Perſons utterly ignorant; for by their Converſation with learned Men, by reading of Books, by Experiments, and particular Obſervations, their Minds are filled with variety of Notions. But becauſe, perhaps, they have given too much Credit to the Reports of others, or perhaps have not throughly examined what they have received by their own Senſes, or have impoſed upon themſelves by falſe Reaſoning; therefore we are not to think, that there is any great Advantage to be had from that Knowledge which is got by theſe Means: On the contrary, it may be very injurious, becauſe the Errors imbibed in our tender Age, before we could make a right Uſe of our Reaſon, may cauſe us to fall into ſtill greater ones.

4. That they ought to be re-examined. 4. Wherefore if we would proceed regularly, we muſt lay aſide all our old Prejudices, and reject them as falſe; not that we are immediately to embrace the contrary Opinions as true, but only ſo to diſpoſe our Minds, as to give Credit only to thoſe Things which we have throughly examined; and to begin natural Philoſophy at the very Beginning. But ſeeing this is a very difficult Task, and it is hard to bring our ſelves to it, becauſe we eaſily perſwade our ſelves, that amongſt the Errors that have privately crept in, there have been alſo a great many Truths, which ought by no means to be rejected; we will therefore go in the common Method, and retaining as many, of our antient Opinions as we can, we will endeavour to lighten that Burden which cannot but be very heavy. And we muſt be very unreaſonable indeed, if we will not review our old Notions, and ſubmit them to a freſh Examination.

CHAP. II.

An Examination of the Notions that precede the Study of Natural Philosophy.

THE Notions which precede the Study of Natural Philosophy, may be reduced to two general Heads. For first, we know that there are *Things* really *existing* in the World; and from hence we think we know, at least in part, *what* they are. These two Considerations are principally to be attended to, that our proposed Examination may be as universal as possible. Let us first see what Motives there are to induce us to believe, that there are certain *Things* really *existing* in the World; and then let us see what Reason we have to believe them to be *such* as we judge them to be. *1. The Whole of natural Philosophy may be comprehended under two Heads.*

2. And to begin with our own selves; we know by experience, that we are capable of diverse *Thoughts*, which cannot be in us, but they must be perceived. The *Idea* of *Existence* is one of these *Thoughts*; and our natural Reason teaches, that *Nothing can have no Properties*, and that *what thinks, must exist*. Hence it is plain how we come by the Knowledge of *our own Existence*. For every Man must necessarily reason in this manner: *I think*; that which thinks must of necessity *exist*; therefore *I exist*. *2. How we come by the Knowledge of our own Existence.*

3. A Man who comes to the Knowledge of his Existence in this manner, knows himself only to be something that exists, the *Idea* of which does not include *Extension* in it. It is true, he may have an *Idea* of a Thing *extended* into *Length*, *Breadth*, and *Height*; but because this *Idea* does not at all include *Thought* in it, the *Thing* that *thinks*, and the *Thing* that is *extended*, are to be looked upon as two *Things* really different from each other; and there is no Reason hitherto for such a Person to think himself an *extended* Thing. And because *That* which *thinks*, which is in us, which we know before all other Things, which we imagine not to be extended, is what we call our *Soul* or *Spirit*, and *That* which we conceive to be extended in Length, Breadth, and Height, and to which we imagine Thought does not belong, is what we call our Body; it is evident, that our *Soul* or *Spirit* is known to us sooner than our *Body*. *3. That our Mind is known to us sooner than our Body, and that these are two really distinct Things.*

4. That we have no other knowledge of the Existence of those Bodies of which the World is composed, but by the different ways of knowing that are in us.

4. As to those Bodies of which the World is composed, (amongst which our own is to be reckoned) it is certain we cannot know that they exist, but by *the different Ways of Knowledge* which are in us; and in order to know if we have made a right Use of them, we will here consider each of them distinctly.

5. What these Ways of Knowledge are.

5. The different *Ways* of Knowledge that are in us, may all be reduced to these Four: *viz. Perception, Judgement, Reason,* and *Sensation.*

6. What is meant by Perception or Imagination.

6. By *Perception* is meant simple Apprehension, or the simple *Idea* which we have of Things, without affirming or denying any thing concerning them; whether this *Idea* raises any Image in our Minds, and so is called *Imagination,* or raises no Image, and so has only the general Name of *Perception* given to it. Thus when we hear the Word *Tree,* the *Idea* which we then form in our Minds, is an *Imagination*; but when we speak of a Thing which cannot be represented by any Image, as of *Doubtfulness*; the *Idea* which we then have, is only simple *Perception.*

7. What is meant by Judgement.

7. *Judgement* is the joining or disjoining of two Things by the Mind, when, according to the different manner of its conceiving them, it affirms or denies the one or the other. Thus when we say, that *the Earth is round,* we join together the two Things which we understand by the Words Earth and Roundness, and this is called *Judgement:* So also when we say that *the Earth is not round,* that is, disjoin those Words; this is also called *Judgement.*

8. What is meant by Reason.

8. *Reason* is a Judgement that depends upon a former Judgement. For Example: After I have judged, *that no even Number can be compounded of five odd Numbers,* and also, *that the Number Twenty is an even Number,* and thence conclude, *that the Number Twenty cannot be divided into five odd Numbers*; this is called, *Reasoning.*

9. What is meant by Sensation.

9. *Sensation,* is *Touching, Smelling, Tasting, Hearing* and *Seeing.*

10. That Perception alone is not a sufficient Assurance of the Existence of any Thing.

10. First, it is evident, that the *bare Perception* of a Thing is not sufficient to convince us that the Thing it self exists; for Instance, because I can *conceive* a *Triangle,* it does by no means from thence follow, *that a Triangle exists.*

11. Neither does Judgement alone fully convince us of the Existence of Things.

11. It is certain also, that our *Judgement* alone is not sufficient to convince us of the Existence of any Thing. For though we cannot help passing our *Judgement* upon many Things; for Instance, *That if two Things be equal to a Third, they are equal to each other; that if Equals be added to Equals, their Sums will be equal,* &c. notwithstanding which, we do not certainly know, that any Things that are equal or une-

unequal exift, and the Truth of our *Judgement* agrees only to the Things that may poffibly exift.

12. We may alfo *reafon* infinitely various ways; and by this means all the Mathematical Truths are difcovered, which are fo different from one another, and from the Principles from which they are deduced: But becaufe the Confequences have a ftrict Relation to the Antecedents, and can contain no more in them than they; and we have already feen that our *Judgement* does not prove that any *Thing* exifts; it follows, that our *Reafoning* proves no more than this, that Things without us may poffibly exift.

12. That Reafon does not convince us that any Thing exifts without our felves.

13. However, [1] there is *one* Exception to this Rule, and that is, *God*: For whoever has the *Idea of Him*, may by Reafon be affured of his Exiftence, if he be confidered as a Being every way perfect, and if Exiftence be owned to be a Perfection. But I fhall not here enter into the Particulars of this Demonftration; the Dignity of this Subject merits to be treated of particularly by it felf.

13. The Exiftence of God may be proved by Reafon.

14. But fince we are here fpeaking only of natural Things, and our *Perception*, *Judgement*, and *Reafon* alone do not prove their Exiftence, we muft certainly have recourfe to our *Senfes* before we can judge that they exift. And we cannot know whether our *Senfes* do fufficiently prove this, nor in what manner they prove it, unlefs we firft define what we mean by *Senfation*.

14. That we ought to make ufe of our Senfes to prove, that the Things without us exift.

15. Long Cuftom makes us many times reafon with fo much eafe and readinefs, that very often, *Reafon* and *Senfation* go together, when we think that *Senfation* only is concerned: Wherefore that we may not confound the one with the other, and fo be led into Error, let us examine this Matter in other Perfons. Let us fuppofe a Man juft born, and that he was in an extraordinary manner endued with the Judgement and Prudence of a grown Perfon; and, that we may examine only one Senfe at a time, let us fuppofe that his Eyes are not yet open, and, that he is put into a Place, where there is no kind of Smell or Noife.

15. The Way to know diftinctly what Senfation is.

16. Now in order to find out what the *Senfe* of *Feeling* is; let this Man's Arm be prick'd with a Needle. It is manifeft, that he will feel the fame fort of Pain that we feel, when at any time we are pricked with a Needle, becaufe we fuppofe him to be fuch a fort of a *Man* as we

16. An Example in a Needle.

[1] *There is one Exception,*) How the Idea of God proves his Exiftence, See *Cartef. Princip. Part.* 1. *Artic.* 14. and *Regis Metaphyf. Lib.* I. *Part.* 1. *Chap.* 5. But this is too nice and fubtle an Argument; that drawn from the Variety, Beauty, Order, and Difpofition of the Creation, does much more fully and ftrongly infer a *God.*

are: Now abſtractedly from any Judgment or Reaſoning, it is evident, that *Senſation* in this Man is nothing elſe, but the being affected with a certain Pain, which belongs to himſelf only. So that if any Perſon were ſo weak as to believe, that a like Pain was in the Needle, we ſhould certainly know for all that, that it was not the very Pain which the Man by *Senſation* felt.

17. That we feel the pricking, and nothing elſe.

17. Let us make ſome Reflection here: In the *Senſation* now mentioned, there are four Things obſervable: Firſt, A *Man* capable of *Senſation*: Secondly, A *Needle*, or the Object that raiſes the *Senſation*: Thirdly, *The Action of a Needle* upon the Body, in which it produces ſome Change: Laſtly, *The Effect of the Action of the Needle, and of the Paſſion of the Body*, namely, *the Pricking*, or *the Pain*. Now ſince 'tis this Laſt only that is known, we muſt conclude, that this *Senſation* not being attended with any Judgement or Reaſon, is nothing elſe but a *confuſed Perception* ariſing from the new State of the Mind, which does not any way make known to us this new State, nor the external Object which cauſes it, and is the Occaſion of the *Senſation*.

18. This Example teaches us what the Senſations of Feeling, Taſting and Smelling are.

18. From what has been ſaid of that *Pain* which is cauſed by a Needle, it is eaſy to apprehend the ſame thing of the other Sort of Senſations, ſuch as *Feeling*, *Taſting*, and *Smelling*. For ſuppoſe the naked Arm of the forementioned Perſon to be lightly touched with a *Feather*, or any other ſoft Thing; ſuppoſe a *red-hot Coal*, or a *Piece of Ice* to be laid on any part of his Body; ſuppoſe *a Drop of Wine* poured on his Tongue, or a *Roſe*, or any other *ſweet-ſmelling Thing* put to him; we can eaſily underſtand, that *the Tickling*, *the Heat*, *the Cold*, *the Taſte*, and *the Smell*, which this Man perceives, are all within himſelf, and belong to him in the ſame manner as the *Pain* did.

19. Ariſtotle had good Reaſon to affirm, that Senſation and Paſſion were the ſame.

19. And ſince there is no Reaſon why we ſhould think differently of the Senſations of *Hearing* and *Seeing* than of the others, we may look upon it as certain, that *Sound*, and *Light*, and *Colours*, are as much in us as *Pain* or *Tickling*. Wherefore we may ſay with *Ariſtotle*, [1] *that all Senſation is a kind of Paſſion*, and when we have any Senſation, whatever ſort it be, we know very well what the Objects raiſe in us, but we don't know what they are in themſelves.

1. Ariſtot. de Anima. Lib. 2. cap. 5. *Senſation conſiſts in being put into Motion, and is a ſort of Paſſion, as was ſaid before; for there ſeems to be ſome Change or Alteration made in us*, [illegible] again, chap. 11. *Senſation is a ſort of Paſſion.*

20. But

20. But this is not the general Opinion of Mankind, who, on the contrary, are apt to think, that the *Sound* which they hear, is in the *Air*, or in the *sounding Body* as they call it; so also that the *Light* and *Colours* which they see, are in the *Flame* or the *Tapestry* which they look upon; and the Reason of it is this, because we do not feel 1 *Sound*, and *Light*, and *Colours* within our selves, as we do *Pain* and *Tickling*, but ascribe them to external Things; and besides, the *Colours* which we see, oftentimes seem to be much bigger than our selves. *20. A vulgar Error.*

21. But to show that these Reasons are not of any Weight, we need only consider, that very often we have a Perception of a Multitude of Things, which we think are without us, and are a great deal bigger than our selves, when at the same time there really is nothing without us, that is the Cause of that Perception. *21. The common Notion refuted by many Experiments.*

22. *First*, In *Dreams* we very often hear Sounds, and see Colours, in the same manner as if we were awake, and we ascribe those Sounds and Colours to external Objects; and we imagine those Colours to be much larger than our selves; though there is indeed nothing without us, to which they can truly be ascribed. *22. I. Experiment.*

23. *Secondly*, Persons in a Phrensie, or in a violent Fever, see also Things without them, which really are not so. *23. II. Experiment.*

24. *Thirdly*, We often hear a *Ringing* in our *Ears*, or a certain Sound which we judge to be at a great distance, when the Cause of it is very near us. *24. III. Experiment.*

25. *Fourthly*, A *Candle*, or any other small Object, at a little distance, appears double to a Person in Drink; or if we press the Corner of our Eye with our Finger; so that there will then appear to be two Objects, when we certainly know, that there really is but one. *25. IV. Experiment.*

1. *Sound, and Light, and Colours*, &c.) In order to account for these Prejudices, we may observe, 1. That Pain and Tickling do much more strongly affect us, and make a greater Change in the State of the Mind, than Sound, and Light, and Colours; so that they are sooner and more easily taken notice of, and imagined to belong to us, and to be in us. 2. When Sound, and Light, and Colours, are at first perceived, there is always something before us, that acts upon us, and to which we ascribe them: But Pain and Tickling often arise from an invisible Alteration of the small Particles of the Body, that is, from a Cause at first unknown to us: Therefore we are a long while used to look upon these as something in us; 'till there appears to be something without us, to which they may be ascribed; and afterwards, when we do sometimes experience, that they proceed from various external Things, we are still apt to think, that they are not in those external Things, but in our selves, because we have been used to think so.

26. V. *Experiment.* 26. *Fifthly*, If in the Dark we wink with our Eyes upon the *Flame of a Candle* at a little diſtance, we ſhall imagine, that we ſee Rays of Light, which ſeem to ſtream from the Flame upwards and downwards in the Air; and yet there is no doubt, but that thoſe Rays ariſe from the Senſation of him that perceives them, and that *out* of him they are nothing; if we conſider, that other Perſons who look upon the Candle at the ſame time, do not ſee them; and the Perſon himſelf who ſees them when he winks, ceaſes to ſee them the Moment that he opens his Eyes, and looks more intently.

27. *There is ſomething remarkable in this Experiment.* 27. We ſhall be more fully ſatisfied, that theſe Rays are not in the Place that we imagine them to be, by this Conſideration; If they were there, it would follow, that upon putting a dark Body between the Eye and the Place where they appear to be, they muſt immediately vaniſh; but they do not vaniſh, but on the contrary are ſeen ſtill, only a little nearer, *viz.* between the Eye and the dark Body that interpoſes. But that which is moſt obſervable in this Experiment, is, that if the dark Body be raiſed by little and little, as if the lower Rays were intended wholly to be hidden by its Interpoſition, they will be ſtill ſeen, when the upper ones wholly diſappear; which could not be, if the Rays were really in the Place which they ſeem to be in.

28. VI. *Experiment.* 28. *Sixthly*, We ſee the Colours through a triangular Glaſs Priſm, very bright, and exactly like the Colours in the Rainbow; theſe we certainly know are not where they appear to be.

29. VII. *Experiment.* 29. Of this kind are the Experiments of *Looking-Glaſſes and Multiplying-Glaſſes*, which repreſent Objects to us, where we are ſure they are not.

30. VIII. *Experiment.* 30. We muſt not here omit an Experiment of thoſe Perſons who have loſt any of their Limbs, an Arm, or a Leg, who, many Months, and ſometimes many Years after they are cured, feel frequent Prickings, and other Senſations, which they cannot help judging to be without them, *viz.* in thoſe Places where their Fingers or Toes would have been, if they had not been cut off. This Judgement is evidently a Miſtake, it being certain, that this Senſation is within themſelves, and not where they take it to be.

31. *A Difficulty which ariſes from the common Cuſtom of Speaking.* 31. This Experiment, together with all the foregoing ones, plainly ſhow, that we have within our ſelves the Senſations of many Things, which we cannot help thinking are without us, though they really are not; and were it not for the common Way of Speaking, which is the uſual

ſual Reaſon given, we ought wholly to lay aſide that vulgar Notion, which we have entertained in our Minds from our Infancy, *viz. that they are without us.* For (may any one ſay) as he who touches a Stick, has reaſon to believe, that the Stick is ſomething without him that touches it; ſo when any one ſays, that he ſees a Colour, he has Reaſon to ſay, that the Colour which he ſees, is ſomething different from him that ſees it, and belongs to the Object.

32. But it is eaſy to get clear of this Difficulty, if we obſerve, that all Languages do not afford equal Plenty of Words upon every Subject. Thus for Example, in the *Latin* Tongue, the Word *Animal* is uſed to expreſs the Kind, under which the whole Species of Animals is contained; the Words *Man* and *Horſe*, are uſed to ſignify thoſe Species; and the Words *Peter* and *Paul*, *Bucephalus* and *Bayard*; to ſignify the Individuals of thoſe Species: But the Caſe is different in the preſent Subject; we uſe indeed in our Language the Word *Senſation*, by which we underſtand, in general, every Perception which we have by the means of Bodies; we have alſo the Words *Feeling*, *Taſting*, *Smelling*, and *Hearing*, to ſignify the particular Species of thoſe Senſations; but if we would deſcend to any thing ſtill more particular; we then want Words, and are forced to make uſe of a general Name, with which we only joyn ſome other Word, to determine its Signification: Whence it follows, that when we ſay, for Example, that *we feel the Heat*, or that *we ſee the Colour*, if we forbear Reaſoning about them, and attend only to the bare Senſation; the *Feeling* ought no otherwiſe to be diſtinguiſhed from the *Heat*, nor the *Seeing* from the Colour, than in any Species, [1] the *Genus* is diſtinguiſhed from the *Difference*: For the Colour and the Heat are Senſations which belong to our own ſelves only, and are nothing more than our own Perceptions.

32. The common way of ſpeaking explained.

1. *The Genus is diſtinguiſhed*, &c.) The Author's Meaning is this, that many People are led into Error, by the Forms of ſpeaking; as when by reaſon of the Fewneſs of Wnrds, our Meaning cannot be expreſſed but by more Wnrds than one; thus when we ſay, that *we ſee Redneſs*, or *feel Heat*; they ſo underſtand it, as if by one of theſe Words we intended to ſignify the Senſatinn it ſelf, and by the other, to ſignify ſnmething without us, which is the Cauſe nf that Senſation. Now if what we call *ſeeing Redneſs*, and *feeling Heat* could be expreſſed by one word, as *Pain*, which is the ſame Thing as *feeling Pain*, or *Tickling*, which is the ſame as *feeling Tickling*, are expreſſed by one Word; we ſhould eaſily apprehend, that the *Redneſs* which we perceive by our Sight, and the *Heat* which we perceive by nur *Feeling*, are no more withnut us, than the *Pain* which we feel when our Arm is pricked with a Needle; or the *Tickling*, when it is touched lightly with a Feather.

33. Though

33. *The Conformity there is betwixt Sight and Feeling.*

33. Though I have been already too long in fhowing that *what we perceive fimply by Sight, is wholly within our felves*; I would yet make appear the entire Conformity there is betwixt *Seeing* and *Feeling*. Let us confider then, that when an Object of *Feeling* affects the Body but lightly, it raifes in us indeed a real Senfation, but it is fo weak an one, that it is gone as foon as the Object ceafes to touch the Organ of Senfation; fo likewife, if the Object of Sight be weak, it is no fooner removed from our Eyes, but we ceafe to fee it. And as an Object of *Feeling*, which ftrikes us with a greater Force, excites a Senfation, which remains after it is feparated from the Organ; in the fame manner alfo, a very ftrong Object of *Sight*, raifes a bright Senfation, which continues for fome time, though we do not look upon it, but turn our Head another way. Thus if any one looks full upon the Sun, and immediately goes into a dark Place, he will fee the Sun there, and fome Sparklings of it.

34. *That we have made ufe of feveral Means of Knowledge, in order to be convinced that Things exift without us.*

34. From what has been faid concerning our *Senfes*, and *the Manner of Senfation*, it is evident, that they make known to us only what is in us, and belongs to us; it is alfo as certain, that they are not alone fufficient to prove to us, that any Thing at all exifts without us which does not belong to us; and this having been already fhown of *every particular Means of Knowledge*, we muft neceffarily, conclude, that we have made ufe of *feveral of thofe Means* in order to be convinced that Things do exift without us.

35. *The Method which we proceed in.*

35. The Method we feem to have proceeded in, is this. Firft, Senfation: Next, we obferve, That this Senfation is fometimes in our own Power, and fometimes not: Whence we infer, that we our felves are not the fole Caufe of our own Senfations; that we contribute fomething towards them, but not fo much, but that we depend alfo upon fome other Caufe; and fo we begin to fee, that we do not exift alone, but that [1] there are many other Beings exifting together with us in the World.

36. *The Exiftence of Things cognizable by our Senfes, is made known to us principally by Reafoning.*

36. Whoever acknowledges this Truth, muft confefs, that he has been in an Error fo long as he thought that the Exiftence of Things without him was proved by his Senfes;

1. *There are many other Beings*, &c.) But even this does not feem fufficiently to demonftrate, that corporeal Things exift: and indeed it does not feem capable of a ftrict *Demonftration*. See *Malbranch. Annot. Chap.* 10. *Book.* 1. *of his Search after Truth*. We muft acquiefce in this; That God has not created us in fuch a manner, that every Judgement which we make of Things exifting without us, fhould be inevitably falfe. See *Cartef. Princip. part* 2. *Artic.* 1.

ſes; for all that theſe can do, is only to be the Occaſion of knowing them; and it is chiefly from Reaſoning that we are aſſured of their Exiſtence.

37. How we know that there are many ſorts of Bodies exiſting.

37. In the ſame manner as we conclude from one ſingle Senſation, that one Thing exiſts; we conclude alſo from different Sorts of Senſations, that there are different Things exiſting; all which, becauſe we imagine them to be extended in Length, Breadth, and Thickneſs, we call *Bodies*.

38. How we come to the Knowledge of our own Body in particular.

38. Amongſt theſe Bodies, there is one which we conſider differently from the reſt, and are obliged, in a ſpecial manner, to look upon as our own; not only becauſe it is always preſent with us, but alſo, becauſe, when any Alteration is made in it by other Things, it cauſes certain Senſations in us; and on the other hand, certain Thoughts in us, produce certain Alterations in that. Thus if I *will* to move my Arm, it is preſently moved; but if I *will* to move another Body, that will not be put into motion by my Will alone.

39. We are not to think that there are as many Things exiſting without us, as we have different Senſations.

39. We may further obſerve, that after the foregoing Reflections have convinced us that our Body is compoſed of many different Parts, ſome of which are the *Organs* of Senſation; the different Senſations we have, are no longer a certain Proof of the Exiſtence of a Number of Things without us: For there is juſt Reaſon to ſuſpect, that the ſame Object may raiſe different Senſations in us, by acting upon different *Organs*; and therefore though the Fire by affecting our Eyes when it is at a great diſtance, raiſes the Senſation of Light; and when it is near, raiſes the Senſation of Heat by affecting our Hands; yet we cannot from hence collect the Exiſtence of more than one Object.

40. A Precaution, in order to be certain of a Number of Things.

40. There is another Miſtake contrary to this, which it is eaſy to fall into, and therefore ought to be avoided. For, does it not ſeem reaſonable to determine with Aſſurance the Exiſtence of many Things, without any danger of being deceived, if in making uſe of but one Senſe, and employing it in but one manner only, it repreſents to us many Objects at the ſame time? Now that we may not be deceived here alſo, we ought to conſider the Medium through which the Action of the Object is tranſmitted; for Example, *a multiplying Glaſs* makes us ſee many Objects at once, when there is only one that really affects our Eyes; which ſhews, that here alſo we may be deceived.

41. Theſe

41. The Signification of the Names which we give to many Things.

41. These two Obſervations teach us, that we ought not to judge raſhly, nor at firſt Sight, that a Number of Things exiſt: However, after having taken all the Precautions requiſite, when we are once plainly and fully convinced of their Exiſtence, by means of the different Senſations which they raiſe in us; we cannot help arguing from the Act to the Power, as Philoſophers call it, which is very natural to all Perſons; and thence concluding, that thoſe Things have within them a Power to affect our Senſes: And hence it is, that we give Names to thoſe Things, ſignifying ſuch different Powers. Thus a Body which raiſes Heat in us, we call a hot Body; and the bare Power of raiſing this Senſation in us, we call the Heat of this Body.

42. A Miſtake about the Signification of Words.

42. Whence it is plain, that they are deceived, who, before they have ſtudied Philoſophy, underſtand theſe Words in a larger Senſe than was ſaid before; for example, who, when we mention the Heat of the Fire, imagine preſently that there is ſomething, I know not what, in the Fire, like that Heat which the Fire raiſes in us; for the giving of a mere Name only to a Thing unknown, does not at all make that Thing known to us.

43. Another Miſtake.

43. They alſo deceive themſelves as fooliſhly, though to appearance, they are more acute, who, in order to prove that there is in the Fire ſomething, I know not what, like that Heat which it excites in us, bid us go near it and try: Now, though we go near it a thouſand times, nay, though we were ſcorched by it, all that this demonſtrates, is only what the Fire does to us, and not what it is in it ſelf. When we ſpeak therefore of the *Heat*, or *Cold*, or *Smells*, or *Sounds*, or *Light*, or *Colours* of Bodies, to ſay, that they are really *Things* which are properly Objects of our Senſes, is a great Miſtake. For he who ſays this, muſt imagine, that we come to the Knowledge of them by bare Senſation only, which is abſolutely falſe.

CHAP. III.

The Manner of applying Philosophy to particular Subjects.

THE Observation which we have now made, is of so great Importance, that it alone shows us the true Method of Philosophy on particular Subjects: For from hence we learn, that in order to find out what the Nature of any Thing is, we are to search for some one Particular in it, that will account for all the Effects which Experience shows us it is capable of producing. Thus, if we would know what the Heat of the Fire is, we must endeavour to find out some particular Thing, by means of which, it is capable of producing in us that Sort of Tickling, or pleasant agreeable Heat which we feel at a little distance from it; and that Sort of Pain, or scorching Heat, which we feel when we approach too near it; and the same Thing must also explain to us, how the Fire comes to rarify some Bodies, and to harden others, and to dissolve others: In a word, it must explain all the Effects that Fire produces. And in order to this, we are principally to guard against any Prejudices we may have entertained concerning it; and not immediately to imagine, that there is in the Fire the same kind of Heat, whether pleasant or scorching, which we feel, when at a distance, or near to it. For indeed, there is no more reason to attribute such sort of Heat to the Fire, than there is to ascribe the same sort of Pain to the Needle, which we feel when we are prick'd by it; and as he would without all doubt be deceived, who should ascribe the same Pain that we feel to the Needle; and would after this, labour to no purpose, in trying to find out the Nature of it; so likewise would it be in vain, after having ascribed to the Fire that sort of Heat which we our selves feel upon that Occasion, to attempt philosophically to explain the Nature of Fire; for nothing solid can be built upon so bad a Foundation, nothing but Conjectures and Chimera's. *1. We must have no Prejudices in Philosophy.*

2. What is now said of Heat, may be applied to all other Things: And by this Rule, every Thing hereafter is to be examined. If that which we fix upon, to explain the particular Nature of any Thing, do not account clearly and plainly for every Property of that Thing, or if it be evidently contradicted by any one Experiment; then *2. When our Conjectures are to be allowed, and when not.*

we are to look upon our Conjecture as false; but if it perfectly agrees with all the Properties of the Thing, then we may esteem it well grounded, and it may pass for very probable.

3. We must for the most part be content with Probability.

3. Thus we must content our selves for the most part, to find out how Things may be; without pretending to come to a certain Knowledge and Determination of what they really are; for there may possibly be different Causes capable of producing the same Effect, which we have no Means of explaining.

4. When a Conjecture may be allowed very probable.

4. Now as he that undertakes to decypher a Letter, finds out an Alphabet so much the more probable, as it answers to the Words with the fewest Suppositions; so we may affirm of that Conjecture concerning the Nature of any Thing, that it is the more probable, by how much the more simple it is, by how much the fewer Properties were had in view, and by how much the more Properties, different from each other, can be explained by it. Thus, for Example; if having taken notice only of four Properties of a Thing, we form such a Notion of it, that the Conjecture we make to explain them, will hold as strong for twenty Properties which we find to be in it; it is certain, that these are so many Proofs that our Conjecture is very good.

5. When a Conjecture is such as may be allowed for a Truth.

5. And indeed there may be so many, and so very different Properties in the same Thing, that we shall find it very difficult to believe, that they can be explained two different ways. In which Case, our Conjecture is not only to be looked upon as highly probable, but we have Reason to believe it to be the very Truth.

6. We ought not too easily to part with a Conjecture that is well grounded.

6. Lastly, To prevent any Scruples that may afterwards arise, we must consider, that, if our Conjecture be otherwise well grounded, it does not lose its Probability, because we cannot upon the Spot explain by it a Property, which appears from some new Experiment, or which we did not before think of: For it is one Thing to know certainly, that a Conjecture is contrary to Experience; and another Thing, not to see how it agrees to it; for though we do not at all see the Agreement, it does not from thence follow, that it is repugnant. And it may be, though we don't see it to Day, we may see it to Morrow; or others who can see further than we, may at one time or other discover it. Thus, as we shall see * afterwards, Telescopes which were not in use till our Days, have confirmed the Hypothesis of *Copernicus, concerning the Motion of Venus and Mercury*, which seemed not very well to agree with *the different Magnitude of* Venus *at different times.*

* Part II. Chap. 14. Artic. 7.

CHAP.

CHAP. IV.

A Caution concerning Words.

1. That we ought to avoid Words, whoſe Meaning we don't underſtand.

SINCE we are accuſtomed to connect our Thoughts with our Words, and oftentimes attend more to the Words than to the Things ſignified by them; that we may not for the future be led into Miſtake by Words, we ſhall not make uſe of any here, nor have regard to any, whoſe Meaning we do not clearly underſtand. Wherefore in this Treatiſe we ſhall wholly neglect ſuch ſpecious Words as *Antiperiſtaſis, Sympathy, Antipathy,* a *Deſire of Union, Contrariety,* and the like. And as we do not uſe them our ſelves, ſo we ſhall have no regard to them from others, unleſs they tell us, very clearly and diſtinctly, what they mean by them, and how we are to underſtand them.

Leſt therefore we ſhould fall into that Fault which we condemn in others, we ſhall here define *the Terms of Art,* which, after the Example of moſt Philoſophers, we ſhall make uſe of.

2. What is meant by a Being.

2. The Word *Being* ſignifies only that which *is* or *exiſts*; for that which does not exiſt, is indeed nothing. For if any Thing be to exiſt next Year, we may affirm, that at preſent it is nothing, and it is only the Idea which we have of it, that is any Thing.

3. What is meant by Subſtance.

3. We underſtand by *Subſtance* here a Thing which we conceive to ſubſiſt of it ſelf, independent of any other created Thing: Thus a Piece of Wax is a Subſtance, becauſe we conceive it to ſubſiſt of itſelf, independent of any other created Thing.

4. That we ought to judge of Things according to our Ideas of them.

4. Obſerve here, that I don't ſay abſolutely, that a Subſtance is a Thing which ſubſiſts of it ſelf; but that it is a Thing which *we conceive* to ſubſiſt of it ſelf, which I ſay on purpoſe to make this Definition of uſe. For though I know very well, that our Conceptions or Imaginations lay no Neceſſity upon *the Things themſelves,* yet they are neceſſary towards *our judging* of them, becauſe we know Things from our Idea's only, and we ought always to judge according to our Thoughts.

5. What is meant by a Mode.

5. We call *that* a *Mode,* or *Manner of Exiſting,* or *an Accident,* which we conceive neceſſarily to depend upon ſome Subſtance. Thus, becauſe we cannot poſſibly conceive the *Roundneſs* of a Globule of Wax to ſubſiſt without

out the Wax, therefore we call it a *Mode* or *Manner of existing*, or *an Accident*.

6. That a Mode cannot be transferred from one Subject to another. 6. From whence it follows, that a *Mode*, or *an Accident*, cannot be transferred from that Substance which is the Subject of it, to any other Substance; for if it could, it would not then have depended entirely upon the first Substance when it was in it, which is absurd.

7. What is meant by a Quality. 7. By the Word *Quality* we mean that, by which a Thing is denominated *such*; Thus *that* in the Fire, whatever it be, which has a Power to raise the Sensation of Heat in us, we call a *Quality* of the Fire, because it is from *this* that the Fire is said to be hot.

8. That the word Quality has not a determinate Signification, but is however useful. 8. That which is to be feared here, and which hath made some over-scrupulous Persons wish that this Word were never used, but wholly suppressed, is, that some Men foolishly think, that they are very knowing, if they can but apply this Word, and some other of the like Sort, to express a Thing which they do not at all understand. However, I cannot agree to them, but think it sufficient, if we do not use it in a bad Sense. For it seems to me (as it did formerly to *Aristotle*) to be very properly used for *that* in general, whatever it be, which we conceive to belong to a Subject, and on the account of which, we give a particular Name to it. Thus, until we clearly and distinctly understand what the Heat of the Fire is, we may call it *a Quality* of the Fire.

9. What is meant by the Words Vertue or Faculty. 9. The Words *Vertue* or *Faculty*, in any Subject, signify in general, the Power which a Thing has to produce some Effect in another Thing. Thus what we just now called a *Quality*, upon this Account, that the Fire is from thence denominated hot; may also be called a *Vertue* of the Fire, if we consider, that it is from *this*, though we know not what it is, that the Fire can heat any Thing.

10. What the Essence of a Thing is. 10. The *Essence* of a Thing, is that which it principally is, or that which constitutes the Nature of it, and by which it is what it is: Thus the *Essence* of a right-lined Triangle consists in this, that it is a Figure terminated by three right Lines. From whence it is evident, that allowing the *Essence* of a Thing, is allowing the Thing it self; and on the contrary, taking away the Essence, is taking away the Thing it self.

11. What the essential Property of a Thing is. 11. We call that *an essential Property of a Thing*, which we conceive so to belong to the Thing, that it is the necessary Consequence of its Essence: Thus, that any two Sides together, are longer than the Third; and that the three Angles are equal to two right ones, are Properties

that

that belong to the Eſſence of a Triangle; becauſe theſe ſo belong to it, that they are a neceſſary Conſequence of a Figure's being terminated by three right Lines. So likewiſe it is the *eſſential Property* of a right-angled Triangle, to have the Square of the Side oppoſed to the right Angle, equal to the Squares of the two other Sides; becauſe this ſo belongs to this Sort of Triangle, that it neceſſarily follows from its being right-angled.

12. We call that *an accidental Property of a Thing*, or in general an *Accident*, which we do not think neceſſary to it; or which ſo belongs to it, that it might have been without it, and yet not ceaſed to have been what it was: Thus the Blackneſs in a Triangle is an *Accident*, becauſe this Colour is not neceſſary to a Triangle; and it may be not Black without ceaſing to be a Triangle. *12. What the accidental Property of a Thing is.*

13. The Production of Something which before was not, we call *Generation*; thus we ſay Fire is *generated*, when we ſee Fire where the Wood was before; ſo likewiſe we ſay a Chicken is *generated*, when we ſee a Chicken in the room of an Egg. *13. What is meant by the VVord Generation.*

14. When a Thing is deſtroyed, or ceaſes to be what it was before, we call it *Corruption*; thus we ſay it is a *Corruption* of the Wood, when we ſee the Wood no longer, but only the Fire in the Place of it; And in the ſame manner we ſay an Egg is *corrupted*, when we ſee the Egg no longer, but a Chicken in its Place. *14. What is meant by that of Corruption.*

15. A Thing is ſaid to be *altered*, when it has undergone ſome Change, but not ſo great a Change as for us not to know it again, or to have a new Name given to it: Thus when a Piece of Iron, which was before cold, is made hot, it is ſaid to be *altered*; for this Change is not ſo great, but we know it to be Iron ſtill, and do not give a new Name to it. We muſt take particular Notice here, that the *Alteration* muſt make but a moderate Change; for if it be ſo great, that we cannot know the Thing thus changed, we do not then ſay that it is *altered*, but that it is *corrupted*. *15. What is meant by the Word Alteration.*

16. By the *firſt Principles* of natural Things, we underſtand, that which is firſt, and moſt ſimple in them, or that of which they are originally compoſed, and beyond which they cannot be reduced. Thus, the *firſt Principles* of a Chicken, are thoſe Things which are united together to compoſe a Chicken, and which are ſo ſimple, that they themſelves are void of all Compoſition. *16. VVhat is meant by the firſt Principles of natural Things.*

17. *That the forementioned Terms signify no more than is contained in the Definition of them.* 17. Now I do not pretend that the foregoing Definitions contain any secret Things in them, nor do I design they should pass for Things very sublime, as some Philosophers have done; but on the contrary, my principal Design in laying them down here, was no other than to explain the Meaning of the Terms which I have defined so distinctly, that no one might be deceived, in putting any other Sense upon them more enlarged or restrained; and to do it in such a manner, that no Fictions might be made out of them.

18. *A Caution about the Meaning of some Nouns Substantives.* 18. I shall here add one Caution about Words, and it is this, That though those which we call *Nouns substantive* were invented to signify Substances; and *Adjectives* and *Verbs* properly signify only Qualities or Modes, or Manners of existing or acting; yet there are a great many Words, which in Grammar pass for Nouns substantive; whose Signification is the same as that of Verbs. Thus when we say that *a Walk is wholesome*, we mean no more than *that it is wholesome to walk*.

19. *An Errour arising from want of attending hereto.* 19. For want of attending to this Rule, the Generality of young Men, when they begin to study, take the Things signified by these Sort of Nouns substantives, to be real Beings, and imagine them to have a particular Existence, and by this Means fill the World with *Scholastick Entities*, and *rational Entities*, which they are many times so possessed with, that they become incapable, all their Lives after, of applying themselves to any Thing that is solid and substantial.

CHAP. V.

The principal Axioms of Natural Philosophy.

1. *The Foundation of natural Philosophy.* AFTER having explained the principal Terms made use of in natural Philosophy; I shall now lay down some important *Truths*, which are self-evident, and which, being the Foundation of all Philosophical Truths, are consequently the principal *Axioms* of Philosophy.

2. *Axiom I.* 2. The first is; that *Nothing*, or *that which has no Existence, has no Properties*. Thus we cannot say that Nothing is hot, or cold, can be divided, or has Parts, *&c.* Therefore where we know there is any Property, whatever it be, there we may affirm, that there is some Thing, some real Being.

3. Se-

3. *Secondly; It is impossible that Something should be made of absolute Nothing; or that mere Nothing can become any Thing.* This *Axiom* is a necessary Consequence of the foregoing one, and proves it self to them who grant *that.* For if Nothing can be made Something, it would follow, contrary to the preceeding Axiom, that Nothing has some Property: Which is absurd. *3. Axiom II.*

4. When I said *that it is impossible for Something to be made of Nothing,* I expressly added the Word *Absolute,* because I do not at all doubt, any more than any other Person, that a Thing may be made out of what has nothing of that Thing in it, or to speak more clearly, may be made out of that which is not that Thing. Thus for Example: No one can doubt, but that Bread may be made of Water and Meal, which are not yet Bread. *4. In what Sense it may be said, that any Thing is made of Nothing.*

5. *Thirdly; No Thing or Substance can be wholly annihilated; that is, so cease to be, that there shall remain nothing at all of it.* Indeed; when any thing wholly disappears, we easily apprehend, that it ceases to be the Thing that it was, in order to become some new Thing: Thus we easily apprehend, that Corn ceases to be Corn, in order to become Meal, and that every Part of the Meal may be still divided into other Parts, so small that they may be utterly imperceptible; but how that which is Something, can become absolutely Nothing, this is utterly unconceivable. *5. Axiom III.*

6. *Fourthly; Every Effect presupposes some Cause.* This is so generally allowed by all the World, that the dullest of all, are led to admire certain Effects, for that very Reason, because they are perswaded that they proceed from a Cause, and that this Cause is wholly unknown to them. If this was not a very true Axiom, we should not so much wonder at that most known Property of a Loadstone for Example; but rest satisfied, with knowing only that the Iron does really approach the Loadstone, without wishing for any Thing further. *6. Axiom IV.*

7. *Fifthly,* Which is a Consequence of the foregoing *Axiom; If we our selves are not the Cause of any Effect, it must necessarily depend upon some other Cause.* Thus, if I know certainly, that a particular Effect which is within my own self, does not depend upon me; I certainly conclude, that it depends upon some other Cause. *7. Axiom V.*

8. *Sixthly; Every Thing, as much as it can, endeavours to continue in that State in which it is.* Thus, if any Thing be square, it will continue always square, and will never of its own self become round, or of any other Figure. This *8. Axiom VI.*

is what others mean, when they say, that Nothing tends to the destroying of it self.

9. Axiom VII. 9. From whence it follows, *Seventhly; That every Alteration is made by some external Cause.* Thus if we see a Flower in a Garden very fresh in the Morning, and in the Evening find it withered; we conclude, that either the Sun, or the Wind, or perhaps some Persons roughly handling of it, have caused this Change, and though we could not at all guess what it was that had made this Change; yet we should ascribe it to some Cause.

10. Axiom VIII. 10. *Eighthly; Every Alteration is always proportionable to the Force of the Agent which causes it.* So that the Thing which is altered continues, as much as it can, in its first State. Thus if a Body, which moves slowly, comes upon another Body at rest, and pushes it before it, we cannot think that it can move this latter Body [1] swifter than it goes it self.

11. That there are many more Axioms. 11. There are yet more *Axioms* which I shall afterwards draw many Conclusions from; but because they are not so general as these, I shall content my self with mentioning them, when I have occasion to make use of them.

12. That Things are here treated of in their natural State. 12. But before we proceed any further; as my Design is to treat of natural Things, and to explain as well the Causes by the Effects, as the Effects by the Causes; that I may not go beyond the Limits of my Subject, but contain my self within the Bounds of the Science I treat of; I expressly declare, that my Design is to consider Things in their ordinary and natural State, and that I pretend not to say, or determine, what they are, or may be, in an extraordinary or preternatural State: Because, I think, it is great Rashness to undertake to determine, how far the Power of God can extend it self, whom I acknowledge to be the Author of every Thing in the World, and who, I believe, can make a Multitude of Things above the Capacity of humane Understanding.

13. That we ought not to say, that there is any Thing which God cannot do. 13. Wherefore I will never venture to affirm, that there is any Thing impossible with God; and instead of speaking in such a manner, which is too common amongst Philosophers, I will content my self, with only saying, that such a Thing is not of the Number of those Things which I know He can do.

1. *Swifter than it goes it self.*) Unless it be endued with an *elastick Force*, which is to be understood as an Addition of *new Force*. See below, Chap. xi. Art. 6.

14. And above all Things, I particularly guard my ſelf againſt enquiring into the *Myſteries* of Faith, and attempting to explain what is obſcure therein; becauſe I am firmly perſwaded, that *that* which God Almighty would have to be a *Myſtery* to the Ignorant and Unlearned, he would have to be ſo likewiſe to the moſt exalted Genius, and to them who think themſelves much greater Philoſophers than I am. *14. That we ought not to be too inquiſitive into Myſteries.*

CHAP. VI.

Of the Principles of Natural Things.

IN order to know what the Principles are, of which natural Things are compoſed, we may take one particular Effect for a Rule, and examine *that*; as for Example, what is done, when the Wood is converted into Fire: For by this Means, it will be eaſy to judge, what paſſes in other Productions of Nature; and this will, as it were, lead us by the Hand, and help us to diſcover what natural *Principles* are, and how many there are of them. Firſt then; becauſe, according to the Maxims before eſtabliſhed, it is impoſſible to conceive the Wood to be wholly annihilated, or the Fire to be made out of abſolute Nothing, therefore we muſt think, that there is Something which before belonged to the Wood, which now belongs to the Fire, and is therefore common to them both. Now this, whatever it be, that ſubſiſts under theſe two Forms, we call *Matter*, as others call it; ſo that *Matter* is one of the Principles of natural Things. *1. Of Matter.*

2. *Secondly*, We apprehend alſo, that there muſt neceſſarily be ſomething elſe added to Matter, which makes it to be Wood and not Fire, or to be Fire and not Wood; and whatever this be, which does not cauſe Matter to exiſt, but only to exiſt in that manner, we call it the *Form*; and this we reckon another Principle of natural Things. *2. Of Form.*

3. *Ariſtotle* obſerved, that though a Thing could not be made abſolutely out of Nothing, it might however be made out of what was not that Thing. Thus a Chicken may be made out of that which is not now a Chicken; ſo that the Non-exiſtence of a Thing, which he calls *Privation*, muſt immediately precede the Generation of it: *3. That Privation ought to precede the Generation of a Thing.*

it: From whence he concludes, that there are three Principles of natural Things, *Privation*, *Matter*, and *Form*.

4. That Privation ought not to be called a Principle. 4. But by making *Privation* a Principle, the Word Principle becomes ambiguous, and quite another Meaning is given to it, than when we said of *Matter* and *Form*, that they were the Principles of natural Things; for it is certain, that *Privation* is not at all a *Thing*, nor does it go to the Composition of any *Thing*.

5. That there are only two Principles, viz. Matter and Form. 5. Besides there is no Reason to make a particular Mystery of this Word *Privation*; for there is no Body but knows what it means; and since it is of no use to explain natural Things by, we conclude, that there are but two Principles of natural Things, *viz. Matter*, and *Form*.

6. That it is necessary rightly to understand what Matter and Form are. 6. But we have not yet made any great Advances in the Knowledge of the Things of Nature: For, He is very far from understanding the Nature of Fire, who knows only thus much, that *Matter* is necessary to the Composition of it, that is, it has something, we know not what, in common with other Things; and that a *Form* is also necessary to it; that is, another Something, we know not what, which gives that particular Existence to the Fire; for, as was observed before, a Thing that is unknown, does not become known, by giving a Name to it; we must therefore consider more distinctly, what *Matter* and *Form* particularly are. We will begin with *Matter*, and try to find out what *that* is, which we call we don't know what, which is common to all the Things in Nature.

CHAP. VII.

Of Matter.

1. The Method of finding out what Matter is. SINCE there are but three Particulars necessary to a perfect Understanding of any Thing, *viz.* its *Essence*, its *Properties*, and its *Accidents*; that we may comprehend fully what *Matter is*, we must distinctly explain what the *Essence* of it consists in; what the *Properties* of it are; and what *Accidents* it is capable of; in order to which, we have no more to do, but to examine all that we conceive any way to belong to material Things, considered as material, that is, to belong to *Matter*; and then exactly to distinguish its *Essence*, from its *Properties*, and *Accidents*.

2. Now

2. The Accidents which belong to Matter.

2. Now according to this Method, if we conſider, that though we do not perfectly underſtand what *Hardneſs, Liquidity, Heat, Cold, Heavineſs, Lightneſs, Taſte, Smell, Sound, Light, Colour, Tranſparency, Opacity*, and the like, are; yet we underſtand enough of them, to know, that they are none of them inſeparable from Matter, that is, it may exiſt without any of them, (for we ſee that ſome material Things are without *Hardneſs*, ſome without *Liquidity*, ſome without *Heat*, and ſome without *Cold*, and ſo of the reſt,) wherefore we ſay, that the *Eſſence* of Matter does not conſiſt in any of theſe Things, but that theſe are accidental only.

3. That Extenſion is not accidental to Matter.

3. But when we conſider Matter as *extended into Length, Breadth, and Thickneſs; as having Parts, and thoſe Parts having ſome Figure, and that they are impenetrable*, we do not judge in the ſame manner of *theſe*, nor think them mere Accidents of Matter. For, as to *Extenſion*; it is certain, that we cannot ſeparate the *Idea* of that, from any Matter whatſoever; becauſe if *Extenſion* does not go along with it, we immediately loſe the *Idea of Matter*, in the ſame manner as the *Idea* of a Triangle vaniſhes, if we ceaſe to have in our Minds the Image of a Figure terminated by three Lines.

4. To have Parts, is not accidental to Matter.

4. As to the *Parts* of Matter; we apprehend them to belong to it ſo neceſſarily, that we cannot imagine any Portion of it ſo ſmall, be it the ſmalleſt we can conceive, but that if it be upon a plain Superficies, we muſt think at the ſame time, that it touches it in one Part, and does not touch it in another; that is, this ſmall Portion of Matter, conſiſts of Parts.

5. That Figure is not accidental to Matter.

5. With reſpect to *Figures*; though it be nothing elſe but the Diſpoſition of the extreme Parts of a Body, and perhaps we cannot determine the particular Figure of a particular Body; it is however manifeſt, that we cannot conceive any Body, be it ever ſo great, or ever ſo ſmall; but at the ſame time we conceive it to have ſome Figure.

6. That Impenetrability is not an accident of Matter.

6. *Laſtly*, With regard to *Impenetrability*; ſince a certain Portion of Matter, ſuppoſe a *cubic* Foot, has all that is neceſſary to ſuch a Magnitude, we cannot conceive how another *cubic* Foot can be added to it, without making two *cubic* Feet: For ſuppoſe any one would reduce them to one *cubic* Foot by Penetration, this would not be ſo much reducing them to one *cubic* Foot, as it would be deſtroying the firſt Suppoſition; whence we are led to think, that the Parts of Matter are in their own Nature impenetrable.

7. Of the Essential Properties of Matter.

7. Now this being so; we must say, that *Extension, Divisibility, Figure, and Impenetrability*, are, at least, *essential Properties* of Matter, because they always go along with it, and cannot be separated from it; and these being all that we conceive to belong to Matter necessarily, for we know of nothing more, we are assured, that the *Essence* of Matter consists in one of these.

8. What the Essence of Matter consists in.

8. And because we conceive *Extension* before the other Three, and because we cannot conceive the other Three, without first supposing *Extension*, [1] we ought to think that *Extension* is that in which the Essence of Matter consists.

9. In what a natural Philosopher ought to acknowledge the Essence and essential Properties of Matter to consist.

9. If it should be here objected; That God could make Something to be the *Essence* of Matter, which neither we, nor any Man living, can understand what it is; we can make no other Answer, but only this; that God, being Lord of all Things, might create them according to his own Will; for we do not pretend to determine by our Reason, that which Reason cannot come at. Wherefore leaving such Sort of Questions to be treated of by those, who are of a higher Profession than that of mere natural Philosophy, and who carry their Views far beyond what Reason can do; we shall contain our selves within the Limits which *that* prescribes, without invading the Territories of others; and conclude from that Knowledge which we have by Reason, that the *Essence* of Matter consists in *Extension*, because that is what we first perceive in it, and from which every Property of Matter is derived, and upon which it depends.

1. *We ought to think Extension*, &c.) It does no more seem to follow from hence; that, because we conceive Extension before any other Properties of Matter, and that those Properties can't be conceived to exist, without first conceiving Extension; therefore *Extension* is the Essence of Matter; than it follows from hence, that *Existence* is conceived before all other Properties of Matter, and therefore *Existence* is the Essence of Matter. But since Extension is a more general Word, and comprehends more under it than material Things, it should seem, that *that impenetrable Solidity* which belongs to all Matter, and to Matter only, and from which all its Properties manifestly flow, may be more truly called the Essence of Matter.

But further; if *Extension* were the Essence of Matter, and so *Matter* the same as *Space it self*; it would follow, that Matter is infinite, and necessarily eternal, and could neither have been created, nor be reduced to nothing; which is very absurd. Beside; it evidently appears from Gravity, as shall be afterwards explained, and from the Motion of Comets, and from the Vibrations of Pendulums, that *Space it self* is not *Matter*. Wherefore not *Extension*, but *solid Extension*, *impenetrable*, which is endued with *a Power of resisting*, may (as was before said) be more truly called the *Essence of Matter*.

10. Fur-

10. Further, that we may carry our Knowledge as far as the Light of Nature will permit; let us consider that the Idea of Extension is so far from depending upon any created Thing, that we can scarce get it out of our Minds, when we try to imagine Nothing, which we believe was before the Creation of the World; which shows that it does not depend upon created Things, that it is not a Consequence nor a Property of them, much less is it an Accident or Mode of existing, but a true Substance. *10. That Extension is not a mere Mode.*

11. It is generally believed, that this is very different from the Opinion of *Aristotle*, because he says in his Metaphysicks, that Matter is not a Thing that can any way answer to Questions which relate to *Essence*, *Quantity*, or *Quality*; and indeed, that it is not a certain determinate Thing; This the *Aristotelians*, for the most part, so interpret, that they would have us think that Matter is not at all extended, nor has any Existence. *11. That this Notion is not agreeable to the greatest part of them, who call themselves the Disciples of* Aristotle.

12. But *Aristotle* seems in this Place to speak of Matter in general; for he expresly distinguishes between *Extension* and *Quantity*, as every one ought, because we can conceive the one without the other. Thus, for Example, a Surveyor of Land conceives at first Sight, that a Field is extended, but he does not know the Quantity of it, till after he has measured it. Now in this Sense of the Word Matter, there is no Inconsistency in saying, that it may be extended, and yet not be any Thing that will answer to those Questions which *Aristotle* there enumerates; for those Questions are to be understood only of Matter under some particular Form: Thus we cannot say of Matter in general, that it is Hot or Cold, that it contains a certain Number of Feet, or that it is such a particular Thing, as Gold, or Wood, or Marble; any more than we can say of an Animal in general, that it is a Horse, and not a Dog, or any other particular Species. *12. That his Opinion is not contrary to it.*

But be this as it will, if *Aristotle* was not of this Opinion, as many of his Interpreters think he was not; we shall make no Difficulty in this Matter, to differ from him; because we do not govern our selves by Authority, when we endeavour to establish Things upon Reason. And there seems to me no Reason to say, that Matter, which is the common *Subject* of all Things, has it self no Existence; for there is no Difference betwixt Non-Existence and Nothing, or having no Properties. *13. That it is not Authority but Reason, which ought to be the Judge of Truth.*

14. Some

14. That Extension in Length, Breadth, and Thickness, cannot be a Mode.

14. Some *Aristotelians*, who may be fatisfied with this Anfwer, will perhaps find fault with me, becaufe I call Extenfion in Length, Breadth and Thicknefs, a Subftance, and not a mere Mode or Accident, as they do. Thus, for Example, when we fpeak of the Extenfion of a Table, they underftand that the Extenfion is a Mode, and the Table the Subftance of it. But it is eafy to make appear, that this is a Miftake arifing from the Manner of Speaking, and is altogether as grofs, as it would be, in fpeaking of the City of *Rome*, to imagine, that thefe were two different Things, one the Mode, and the other the Subftance. But to clear all Difficulty in this Matter, we muft obferve, that it is of *the Nature of a Subftance to be able to exift without its Mode*; on the other hand, *The Nature of a Mode is, not to be able to exift without that Subftance of which it is the Mode.* For it is evident, [1] that the whole Extenfion of the Table can fubfift without being a Table, but on the contrary, there can be no Table without Extenfion. Wherefore, fo far ought we to be from faying, that Extenfion is a Mode of which the Table is the Subftance, that we ought to fay, on the contrary, that Extenfion is the Subftance, and the Form of the Table the Mode.

15. Whence it is that natural Philofophy has been hitherto fo barren.

15. *Laftly*, They who deny Extenfion to be the Effence of Matter; cannot diftinctly tell us what they mean by Matter, nor in what its Effence confifts; and they lay down fo obfcure a Thing for a Principle, that it is impoffible to draw any Confequence from it, that can enlighten our Minds, or ferve to clear up any Truth. Wherefore we need not be furprized, that their Philofophy is fo barren, and that it is not capable of explaining the fmalleft Effect in Nature. Let us now fee if the fame may be affirmed of the Principle which we have maintained.

1. *That the whole Extenfion of the Table*, &c.) Yes, if neither the *Table*, nor the *Matter it felf, or Subftance of the Table* exifted. This Inftance therefore does not prove, that Extenfion is *that* Subftance or Matter of the Table, but that there muft neceffarily be fome *Subftance* fubfifting under *the Form of the Table*, which is it felf extended; which extended Subftance is not Extenfion it felf, but fubfifts in Extenfion or extended Space.

CHAP. VIII.

Some Corollaries of the foregoing Notion.

FROM what we have now laid down concerning the Effence of Matter, we infer in the firft place, [1] *that what the Philofophers call a* Vacuum *cannot poffibly be:* For by a *Vacuum* they mean a Space void of all Matter; but by Space (or Extenfion) we mean the fame Thing as Matter; and to ask if there can be any Space without

1. That it is impoffible there fhould be what the Philofophers call a Vacuum.

1. *That what Philofophers call a* Vacuum, *&c.*) This is confiftently enough faid by him, who affirms the Effeoce of Matter to be Extenfion: But it is very evident from Gravity, (which fhall afterwards be briefly explained) that there muft not only be a *Vacuum* in Nature, but that it is the far greateft Part.

Befides, a *Vacuum*, as I faid now, is demonftrated from the Motion of *Comets*. For fince *the Comets are carried with a continual Motion through the Heavenly Spaces, from every Part, and all VVays, and to all Parts* (in Orbits which cut the Orbits of the Planets tranfverfely every way) *it is evident from thence, that the Heavenly Spaces, muft be void of any fenfible Refiftance, and confequently of any fenfible Matter.* Newt. Optic: p. 310. See alfo the Notes on Part II. chap. 25, 26.

This is ftill further evideot from the *Vibrations of Pendulums*, for they meet with no Refiftance in Spaces, out of which the Air is exhaufted; wherefore it is plain, here is no fenfible Matter in thofe Spaces, nor in the occult Pores of the Bodies themfelves. The Fiction of *Cartes*, that the *Smalnefs* of his fubtil Matter is the Reafon why the Refiftaoce is infenfible, for a fmall Body ftriking againft a large one, cannot move it in the leaft, nor hinder its Motioo, but is reflected with the Whole of its own Motion; this is very weak, and contrary both to Reafon and Experience. For the famous Sir *Ifaac Newton* has demonftrated, that the *Denfity of fluid Mediums is pretty nearly in proportion to their* Refiftance (Opt: p. 311.) and that they are very much miftaken, *who think that the Refiftance of projectile Bodies is infinitely diminifhed, by the infinite Divifion of the Parts of the Fluid*; (Princip. Book II. Prop. 38. Corol. 2.) *For on the contrary, it is evident, that the Refiftance can be but a very little diminifhed, by the Divifion of the Parts of the Fluid* (Ibid. Prop. 40. Corol. 3.) For, *the refifting Forces of all Fluids are very nearly as their Denfities.* For *why* fhould not the fame Quantity of Matter, make the fame Refiftance, whether it be divided into a great many very fmall Parts, or into a few large ones? Wherefore, if there were no *Vacuum*, it would follow, that a Body moved in Air, or in a Place out of which the Air is exhaufted, would meet with as much Difficulty, as if it were moved in Quick-filver; which is contrary to Experience, and therefore it is evident, that there is a *Vacuum* in Nature, and (as was faid before) that it is much the greateft Part.

Since therefore the Effeoce of Matter does not confift in *Extenfion*, but in *impenetrable Solidity*, we muft fay, that the whole World is made up of *folid Bodies* which move in a *Vacuum*. And we need not fear, that the Phænomena of Nature fhould not be fo well explained thereby; for the Explication of thofe Phænomena which feem chiefly to depend upon a *Plenum*, viz. The *Barometers*, *the Flux and Reflux of the Sea*, *the Motion of the Stars*, *and of Light*, thefe can be more eafily and fully explained upon other Principles (as fhall be fhown hereafter;) but as to the other Phænomena of Nature, which depend upon Caufes not fo general, the Explication of them is the fame in our Syftem as in that of *Cartes*.

Matter,

Matter, is the fame as to ask, if there can be any Matter without Matter, which is a manifeft Contradiction. And it fignifies nothing to fay, that we can conceive a Space, in which we fuppofe there is no Light, Colour, Hardnefs, Heat, Weight, in a Word, in which we fuppofe there is not any one Quality that we can imagine; for when this is done, and all thefe Things denied of Extenfion, it is the *Accidents* only that are taken away from the Thing, whofe real Effence is at the fame time fuppofed.

2. What the Confequence would be, if God fhould annihilate the Air in a Room.

2. And here we fhall not trouble our felves to give an Anfwer to any one who fhould put the following Queftion to us; Whether God could not by his Omnipotence make a *Vacuum*, by annihilating all the Air in a Room, and hindring any more from coming in its Place? For, as we faid before, it does not belong to us determine how far the Power of God can extend it felf. But if the Queftion be a little altered, and we be only asked, what *we conceive* would follow, if God fhould annihilate all the Air in a Room, and not fuffer any other to enter in its Place? We fhould return for Anfwer, (not concerning our felves with what would come to pafs without the Room,) that the Walls would approach one another fo near, that there would remain no Space betwixt them.

3. That the Difpofition of the Walls in making a Room, depend upon the Extenfion of the Matter that is contained between them.

3. Perhaps it may be urged by fome, that the Walls of a Room exift independent of what is contained between them, and confequently that they might continue in the State they were, without approaching one another, though what is between them were annihilated. To which I anfwer; that it is very true, that the Exiftence of the Walls does not depend upon what is contained between them; but the State they are in, or the Difpofition of them, in order to compofe a Room, this depends upon Extenfion, or fome Matter which is between them, and confequently, this Extenfion cannot be deftroyed without deftroying the Difpofition which the Walls were in before, though not the Walls themfelves.

4. What is meant by Place.

4. *Secondly*, We are to underftand that *internal Place*, or *the Space which any Body poffeffes*, [1] *does not at all differ from the Body it felf.* And therefore when we fay a Body changes its Place, we mean its *external Place*, that is, *with regard to the Superficies of other Bodies with which it is furrounded, to the different Parts of which, it may be differently applied.*

1. *Does not at all differ*, &c.) This indeed is not true; but it makes no difference as to the Explication of the Phænomena of Nature. For the true Definition of *Place*. See the *Notes on Chap.* x. *Art.* 2.

5. *Thirdly*,

5. How Bodies are rarefyed and condensed.

5. *Thirdly*, When a Body appears to take up more Room than it did before, without our perceiving any Matter to be added to it, which is what we call *Rarefaction*, we conclude [1] that some very subtile Matter has entered into it, and distended its Parts. So likewise, when a Body appears to take up less Room than it did before, without our perceiving any thing to be taken from it, which is what we call *Condensation*, it is our Opinion, that some imperceptible Matter is gone out of its Pores, and that by this means its Parts approach nearer to each other. For since Extension and Matter are to us the same Thing; we cannot conceive that a Body should appear more or less extended, let the Manner be what it will, but that it must have more or less Matter.

6. In what Sense it is, that we say that a rarefyed Body acquires nothing, and a condensed Body loses nothing.

6. And this does not hinder, but that we may say with *Aristotle*, that a *rare* Body is that, which has but a little Matter, and possesses a large Space, and a *dense* Body, is that which possesses a small Space, and has a great deal of Matter; or, which is the same Thing, that a rarefy'd Body does not acquire any new Matter, nor a condensed Body lose any of its own. For this imperceptible Matter which we speak of, ought to be considered as a Thing that is foreign, and which does not at all belong to the Body it enters into, or comes out of, when it is rarefyed or condensed. Thus when Paste is turned into Bread, it is rarefyed before, and while it is baking, yet we don't say, because of this, that we have more Bread than we had Paste; though it is visible, that a great deal of Air is got into those large Spaces which we call *the Eyes of the Bread*; because, what is thus got in, is not what we call Bread: So also when we press the Crumb of the Bread in our Hand, and bring it to a less Compass; though we are sure that a great deal of Air is squeezed out of it, yet we don't say that there is less Crumb than there was before; because there remains yet all that we call Crumb, and the Air which went out of it, did not belong to it.

7. Whence it is that a Chesnut bursts upon the Fire.

7. What we have now said about *Rarefaction*, may be thought perhaps hardly to agree with what we experience in a Chesnut, which, when put upon the Fire, bursts with a Noise; for it may perhaps be imagined,

1. *That some very subtile Matter*, &c.) When any Body is rarefyed, it is often very manifest, that its Parts are distended by the Entrance of the Air, or some more subtile Matter. But this does not follow from a *Plenum*, but either from the Liquidness, or from an elastick Force, or from Gravity and Pressure, or from some accidental Motion in that subtile Matter which enters into the Pores of the rarefyed Body.

that

that the fubtile Matter which enters through the Pores of the Husk of the Chefnut, may come out with the fame eafe as it enters in, without breaking, or making any Noife. But this Difficulty is eafily refolved, if we confider, that it is not the foreign Matter that enters in, and comes out of the Chefnut, which is the immediate Caufe of the Noife; but the more grofs Parts of the Chefnut it felf, which are torn in Pieces, and put in fuch Motion, [1] by the fubtile Matter which enters the Pores like fo many little Wedges, that they break the Husk with a Noife.

2. That the VVorld is indefinite.

8. *Fourthly*, We conclude, [2] that *the World is indefinite*, becaufe at how great diftance foever we fet its Bounds, it is impoffible for us not to imagine Extenfion to be ftill beyond. Now Extenfion and Matter, being, as was faid before, the fame Thing; we have no Notion of the World's being fo big, but we can imagine it to be ftill bigger.

9. That it is impoffible that there fhould be many VVorlds.

9. *Fifthly*, It is evident, that though we can fee no Reafon why there may not be many Bodies like to our Earth, and capable of containing many Animals, as that does; yet it is impoffible [3] *that there fhould be many Worlds*; for this, in which we are, poffeffes all that Space which we are able to conceive.

10. That the Matter of the Heavens, and of the Bodies upon this Earth, are of the fame Kind.

10. *Sixthly*, Becaufe the Idea we have of the Extenfion of the Heavens is the fame as that of the Extenfion of Things here below, we ought to think [4] *that they are of the fame Kind*; and it is no Objection againft this, to fay, that the Extenfion or Matter of the Heavens is brighter, and not fo mutable as that of Things here below, becaufe this Difference regards only the Accidents of Matter, and not the *Effence* of it.

1. *By the fubtile Matter*, &c.) Or rather by the included Air, which is very much rarefyed by the Heat, and tears the Chefnut in pieces.

2. *That the VVorld is indefinite*, &c.) From the Hypothefis of a *Plenum*, it muft neceffarily follow, that the World is really and truly *infinite*, nay, that it is uncreated and eternal, (as was faid before.) But fince it is evident, that Extenfion may exift without Matter; whether the material World be infinite or no, fuch is the Shortnefs of humane Underftanding, that it cannot certainly be known: Therefore it may very well be called indefinite ftill.

3. *That there fhould be many VVorlds*, &c.) It is evident, that there may be many Earths like this Globe of ours; that there may alfo be many Syftems of Stars and Planets difperfed through the vaft Immenfity of Space; but whether there be a *Plenum* or no, *the whole Univerfe*, which may properly be called the *VVorld*, can of Neceffity be but one.

4. *That they are of the fame Kind*, &c.) This is equally true, whatever be the Effence of Matter.

11. *Laftly*

11. *Lastly,* We cannot affirm, that a Veſſel filled with Lead [1] contains more Matter than if it were filled with Wax, though it be heavier; for Heavineſs is not eſſential to Matter, but only Extenſion, which we ſuppoſe to be equal in them both. *11 That two equal Bulks contain an equal Quantity of Matter.*

12. That Notion alone which we have eſtabliſhed concerning the Eſſence of Matter, has been the only Principle we have made uſe of, to anſwer all the foregoing Queſtions with ſo much Eaſe; whence there is Room to believe, that we may with the ſame Eaſe give a ſatisfactory Anſwer to many more, if we reaſon in the ſame manner about any of its *Properties:* The firſt that offers it ſelf is *Diviſibility,* which is the more copious, becauſe all its Variety of Figures depend upon it. *12. That the Properties of Matter may make a Diſcovery of many other Truths.*

1. *Contains more Matter, &c.* This is abſolutely falſe, as ſhall be fully demonſtrated afterwards, when we come to diſcourſe of the Nature of Gravity.

CHAP. IX.

Of the Diviſibility of Matter.

WHEN we conſider a determinate Portion of Matter without Prejudice, and compare it with other Portions of Matter with which it is encompaſſed, we eaſily conceive that its particular Exiſtence is wholly independent of thoſe that are near it, and that it does not ceaſe to be what it is, by being joined or united to other Portions of Matter; the firſt Portion of Matter therefore is ſeparable from thoſe with which it is united; and this ſhows the Diviſibility of Matter; and the Poſſibility of having its Parts divided into ſtill leſſer Particles. *1. That Matter is diviſible.*

2. Indeed, when we conſider the Power of God, and his abſolute Dominion over all Things that are in the World, we cannot doubt, but that he is able to make certain Parts of Matter of ſuch a Nature, that there is no Being in the Univerſe capable of dividing them; whence it would follow, that theſe Parts would not at all differ from thoſe little Bodies, which *Epicurus* calls Atoms: But this Property of not being capable of being divided by any external Being, is arbitrary, and not built upon any natural Principle, but only upon a mere Suppoſition, which does not alter their real Nature; and therefore we may, notwithſtanding this, hold it for certain, that all Matter *2. Of Epicurus's Atoms, and that they are really diviſible.*

is

is divisible. The whole Difficulty in this Matter is, how many Parts a certain Portion of Matter can be divided into.

3. That Matter is divisible in all Points that can be assigned.

3. In order to solve this Difficulty, we must remember, that all the Variety that we can conceive to be in Matter, arises from the Forms which distinguish its Parts from each other; for of itself it is perfectly homogeneous, that is, all alike, being only a Substance extended into Length, Breadth, and Thickness; wherefore we cannot but think, that whatever it is capable of in one Part, it is also capable of in all other Parts. As therefore we cannot doubt but that it is divisible in some Points, so also is it divisible in all the Points that can be assigned.

4. That the Number of Points assignable in Matter, is indefinite, and that Matter is indefinitely divisible.

4. Now that the Number or Points which we can conceive in a determinate Quantity of Matter (*an Inch* for Example) is indefinite; there are many Demonstrations in Geometry to show, one of which I shall give, which seems to me very easy. Let two indefinite Lines AB, CD, be drawn parallel to each other, and at an Inch distance; then the Line EF, which is perpendicular to them, and limited by them, will be also an Inch long. Then let the Point A, in the Line A B, be taken on the left Hand of the Line EF, and, if you will, at an Inch distance from it, on the Line CD to the right Hand of EF, let as many Points G, H, D, *&c.* as you please be taken, and at any distance from each other; to which let as many streight Lines be drawn from A; as AG, AH, AD. Then it is evident; that the Line AG will pass through the Point I of the Line EF; that the Line AH will pass through the Point L which is higher; and the Line AD will pass through the Point M which is higher still; and so on; and because the Line CD is indefinite, and an indefinite Number of Points, such as G, H, D may be taken upon it, it will follow, that Lines drawn from A to all those Points, will mark an indefinite Number of Points on the Line EF different from each other, and which approach nearer and nearer to the Extremity E, without any one of them ever passing through the Point E, because the Line CD is supposed to be parallel to AB. Wherefore, (because the Length of EF was taken at pleasure, and the same Demonstration holds for any other Length whatsoever;) we must acknowledge, that an indefinite Number of Points may be assigned in any determinate Portion of Matter, and consequently that Matter is indefinitely divisible.

Tab.I. Fig.1.

5. This

5. This Truth may alfo be demonftrated from this Confideration, that there are fome Quantities that are incommenfurable, that is, have no common Meafure. Thus, fuppofe ABCD to be a Square, it may be geometrically demonftrated, that the Side AB, is incommenfurable to the Diagonal AC. Let us then imagine in our Minds the Line AB, which is an Inch long fuppofe, to be divided into a hundred Thoufand equal Parts, and every one of thefe into a hundred Thoufand other Parts that are equal alfo, and again, every one of thefe into a Hundred Thoufand other Parts equal to one another ftill; we may go on in the Divifion thus, for an Age together, without ever being able to come at Parts fo fmall, as to fay, that the Line AC contains a certain determinate Number of them and no more. Now this could not be fo, if Extenfion were not indefinitely divifible; for then after we had divided the Line AB, for inftance, into as many Parts as it is poffible for Extenfion to be divided into, the Line AC would neceffarily contain [1] a certain determinate Number of thofe Parts. We muft therefore conclude, that every Thing which is extended, and every Portion of Matter, is indefinitely divifible. *5. Another Demonftration.* Tab. I. Fig. 2.

6. This Conclufion of *Ariftotle's*, hath been affented to by all his Followers, except a very few; and they departed from it only, becaufe they thought they contradicted themfelves: For, fay they, if two Bodies be fuppofed unequal, and if they can be divided indefinitely, it will follow, that the Number of Parts of which the one is compofed, is equal to the Number of Parts of which the other is compofed; and from thence it will follow, that they are both equal, which is contrary to the firft Suppofition. *6. An objection againft this.*

7. But here is a double Miftake. Firft, they did not confider, that Equality and Inequality are Properties of finite Things, which can be comprehended and compared together by humane Underftanding; but they cannot be applied to indefinite Quantities which humane Underftanding cannot comprehend or compare together, any more than it can a Body with a Superficies, or a Superficies with a Line. But, if it could be faid, that of two unequal Bodies, divided in the foregoing Manner, as the *7. An Anfwer to this Objection.*

1. *A certain determinate Number, &c.*) For if the Li[illegible] AB could be divided [illegible]to thofe fmalleft Parts, the Line AC, and all other Lines could be divided alfo into them; fo that one of thofe fmalleft Parts would be the common Meafure of the Lines AB, AC, and of all other Lines. Tab. I. Fig. 2.

Line EF was divided, the Number of the Parts in the One, was equal to the Number of the Parts in the Other; we could not conclude from thence, [1] that the two Bodies themſelves were equal; becauſe the Parts of the one, are bigger in Proportion than the Parts of the other: There is therefore no Contradiction in this particular, but the foregoing Demonſtration holds in its full force.

8. *Another Objection.* 8. Others attack the indefinite Diviſibilty of Matter, another way; by ſaying, that it would from thence follow, that a ſmall Portion of Matter, ſuch as a Cube, a quarter of an Inch high, might be divided into as many thin ſquare Pieces, as would cover the whole Globe of the Earth, if it were much bigger than it is; which, they think, is abſurd.

9. *Anſwer.* 9. But theſe have no more Reaſon of their Side than the other; for their Objection is founded upon this ſingle Maxim of their own, *That every Thing is abſurd, which our Imagination can't comprehend:* This is a very groſs Miſtake, and unworthy of a Philoſopher, who cannot but know, that there are an infinite Number of Truths, which it is certain our Comprehenſion cannot attain to. Many Examples might be given of this, but I ſhall content my ſelf with Two, both which relate to the Subject we are now treating of, *viz.* The Sheets of Gold made by Gold-beaters, and the Gold Wire made by Wire-drawers.

10. *Concerning the Diviſion of Gold made by Gold-beaters.* 10. In order to a clear Conception hereof, we muſt firſt know, that it appears by Experience, that the Weight of an equal Quantity of Gold and Water is as 19 to 2, ſo that if a Cubick Foot of Water weighs 71 Pounds,

1. *That the two Bodies themſelves are equal,* &c.) What is ſaid of Quantities decreaſing infinitely little, may alſo be underſtood of Quantities increaſing infinitely great; that is, Quantities infinitely great, are not therefore all equal to each other. For a Line drawn from a Point infinitely, one way, is but half a Line drawn from a Point infinitely, two ways. And a Rectangle of an infinite Heighth, upon a finite Baſe, may be $\frac{1}{2}$, $\frac{1}{3}$, &c. of a Rectangle of an infinite Height alſo, upon a proportionable Baſe. And, in Heterogeneous Quantities, an infinite Line, is not only not equal, but is infinitely leſs than an infinite Superficies; and an infinite Superficies, than an infinite ſolid Space. And in a ſolid Space, a Cylinder infinite in Length, is not only not equal in Quantity, but is really infinitely leſs, than an infinite ſolid Space of two Dimenſions, *viz.* Length and Breadth; and an infinite ſolid Space of two Dimenſions, is infinitely leſs than an infinite Space of all the Dimenſions. Whence, by the way, it appears, how weakly they argue, who, becauſe *Space* (and the ſame is true of *Duration*) may be divided into innumerable Parts which are unequal; and in *infinite Space* (or *Duration*) the Number of the greateſt Parts is as much infinite as that of the leaſt; which they think abſurd, becauſe they believe all Infinites to be equal in every reſpect; conclude from hence, that there can be no ſuch Thing at all as Infinite Space (or *Duration.*)

[1] a cubick Foot of Gold will weigh 1349 Pounds or [2] 21584 Ounces. [3] Now a cubick Foot contains 2985984 Cubick Lines, and therefore [4] an Ounce of Gold contains $138\frac{7392}{21584}$ cubick Lines. Wherefore an Ounce of Gold, reduced into the Form of a Cube, will be [5] very near $5\frac{1}{7}$ Lines high, and its Base [6] about $26\frac{22}{49}$ square Lines. This being so, the next Thing to be known, is, that the Gold-beaters make out of an Ounce of Gold 2730 whole Leaves of 34 square Lines each, besides what they call the Waste, which is the small Shreds that are cut off, and amount to almost half: The Superficies of [7] every one of these Leaves is 1156 Lines square, so that if they were all placed regularly by one another, they would [8] make one Superficies of 3155880 square Lines; to which if we add [9] but a third Part, which is the least that goes into Shreds, it will follow, that a Gold-beater makes out of an Ounce of Gold 4207840 square Lines. Now since this Superficies [10] exceeds the Base of a Cube of Gold of an Ounce weight 159092 times, it is certain, that That Cube, which, as was said before, did not exceed $5\frac{1}{7}$ Lines in Height, is divided into 159092 square Leaves.

11. Though this Division of Gold be very surprizing, yet it is very far short of what is done by Wire-drawers. I have seen several Ingots of Silver in the Figure of Cylinders, which weighed eight Pounds a piece; one of them, which seemed to me more regular than the rest, was two Foot and eight Inches long, and two Inches and

11. The Division of Gold by Wire-Drawers.

1. *A cubic Foot of Gold*, &c.) For 1 : 19 :: 71 : 1349.

2. *Or 21584 Ounces*) For 16 Ounces make a *French* Pound. See *Prestet. Nouvel. Elem. Mathemat.* 3. *Edit.* 1. *part. lib.* 2. *pag.* 55.

3. *Now a cubic Foot*) The Proportion between a Line and a Foot, is as 1 to 144; now in this continued geometrical Proportion, the Number is 2985984: Therefore because Cubes are in a triplicate Ratio of their Sides, a cubic Line is to a cubic Foot, as 1 to 2985984, that is, a cubic Foot contains 2985984 Lines.

4. *An Ounce of Gold*) A cubic Foot of Gold, which weighs 21584 Ounces, contains 2985984 cubic Lines; therefore by the following Proportion, it is, 21584 *Ounces* : 2985984 *cubic Lines* :: 1 *Ounce* : $138\frac{7392}{21584}$ *cubic Lines.*

5. *Very near $5\frac{1}{7}$ Lines high*) For the Cube Root of $138\frac{7392}{21584}$ is very nearly $5\frac{1}{7}$, though $5\frac{1}{6}$ is still nearer, For the Cube of $5\frac{1}{6}$ is $137\frac{199}{216}$; And the Cube of $5\frac{1}{7}$ is $136\frac{8}{343}$.

6. *About $26\frac{22}{49}$ square Lines*) For the Square of $5\frac{1}{7}$ is pretty nearly $26\frac{22}{49}$.

7. *Every one of these Leaves*) For the Side of a Leaf, was said before to be 34 *Lines*, the Square of which is 1156.

8. *Make one Superficies*) Multiply 1156 the Number of square Lines in one Leaf, by 2730 the Number of Leaves, and it will make 3155880.

9. *But a third Part*) To which Superficies, if we add a third Part of 3155880, that is, 1051960 it will make 4207840.

10. *Exceeds the Base*) That is, the Superficies 4207840, contains the Base of that Cube, or $26\frac{22}{49}$, 159092 times.

nine

nine Lines about; so that [1] the Cylindrical Superficies was 12672 square Lines. After this Superficies was covered over with several Leaves of Gold, which all together weighed half an Ounce; the whole Cylinder was drawn through Holes made in a Plate of Steel, till it became such as the smallest Wire that is made in this City; I took 25 Fathom or 150 Foot of it, and weighed them in an exact pair of Scales, and found that they weighed but 36 Grains, wanting about $\frac{1}{64}$ of a Grain. Wherefore [2] the whole Cylinder ought to have been drawn into a Wire of 307200 Foot long: Whence it follows, [3] that it is 115200 times longer than it was before, and that its Superficies is become [4] three hundred and forty times as much. To which if we add, that when this small Wire is made into a thin Plate, to cover Silk with, [5] the Superficies is twice as

1. *The Cylindrical Superficies*) For two Feet and eight Inches (that is 384 Lines) which is the Height of the Cylinder, multiplied by two Inches and nine Lines (that is 33 Lines) which is the Circumference of the Base, makes 12672.

2. *The whole Cylinder*) First let the whole Cylinder (which, as was said before, was 8 pounds) be reduced into Grains

by multiplying:
- 8 Pounds by 16, which makes 128 Ounces.
- 128 Ounces by 8, which makes 1024 Drachms.
- 1024 Drachms by 3, which makes 3072 Scruples.
- 3072 Scruples by 2, which makes 6144 half Scruples.
- 6144 half Scruples by 12, which makes 73728 Grains.

Then by the following Proportion; 36 *Grains* : 150 *Feet* : : 73728 *Grains* : 307200 *Feet*.

3. *That it is 115200 times longer*) For multiply 2 Feet and eight Inches (which is the Length of the Cylinder) or 32 Inches by 115200, and it will make 3686400 Inches, that is, 307200 Feet (the Length of the whole Wire.)

4. *Three hundred and forty times as much*) Let the whole Cylinder of Silver which is to be drawn into Wire, be called A, and suppose another Cylinder B of an equal Base, but 115200 times higher, and let the Cylinder of Wire be called C. It is manifest that the Superficies of the Cylinder B, and the Superficies of the Cylinder A, are to one another as 115200 to 1, *that is*, as the Height of the Cylinder B to the Height of the Cylinder A, *that is*, as the Base of the Cylinder A, to the Base of the Cylinder B (for the Bases of equal Cylinders are reciprocally as their Heights) *that is*, as the Base of the Cylinder B, to the Base of the Cylinder C. Now if we suppose, according to *Cavallerius's* Doctrine of Indivisibles, that the Superficies of Cylinders consist of an infinite Number of Circumferences of Circles equal to the Bases, then the Superficies of the Cylinder B, will be to the Superficies of the Cylinder C, as the Circumferences, or as the Radius's of their Bases; now the Radius's are to one another in a subduplicate Ratio of the Area's of the Circles: If therefore the Superficies of the Cylinder B, be supposed 115200, the Superficies of the Cylinder C will be a mean Proportional between 115200 and 1 (that is, 340 very nearly) and the Superficies of the Cylinder A will be 1. *Q. E. D.*

5. *The Superficies is twice as big*) If the Cylinder be made flat, its whole Superficies is made into two Parallelograms, which because they lie one upon another, form a thin Parallelepipedon, capable of being made as thin again, which is done by the

as big; ſo that it then is encreaſed to ſix hundred and eighty times as much as it was at firſt, 6 and therefore contains 8616960 ſquare Lines. Now after this Wire is made into ſo thin a Plate, its Superficies is ſtill covered all over with Gold; ſo that only half an Ounce of Gold with which the Plate is covered, is made ſo thin, that its Superficies is 8616960 Square Lines. 7 Which Superficies exceeds 325795 times the Baſe of a Cube of Gold of an Ounce weight, and twenty ſix ſquare Lines and $\frac{22}{29}$ in Breadth; from whence it follows, that the Thickneſs of the Gold which the Silver Plate is covered with, is not above $\frac{1}{325795}$ 8 of half the Height or $\frac{1}{651590}$ of the whole Height of a Cube of Gold of an Ounce weight; ſo that the Quantity of $5\frac{1}{7}$ Lines is divided into 651590 equal Parts.

12. If we conſider further, that Gold is capable of being divided ſtill more, if there were any Occaſion for it; and above all, if we conſider that what we have now examined is done by *Men*, and with Inſtruments that are very groſs and dull, and that there are in Nature many Things, which are vaſtly more fine and ſubtile; we ſhall clearly ſee, that what exceeds our Imagination, is not therefore impoſſible; and that it is not for us to preſume, as many do, to ſet Bounds to the Power of God.

12. The foregoing Conſiderations of the Diviſion of Matter, teach us to form a better Judgement of the Power of God.

13. Laſtly, We are carefully to obſerve, that That Diviſion which we make in our Minds and Imaginations, makes no Alteration at all in Matter, but that all real Diviſion ariſes from Motion; that is, in order for a Portion of Matter to be really divided from that to which it is united, it muſt neceſſarily be ſeparated from it. And hence it is, that *Motion* is ſo neceſſary, and the Knowledge of it ſo uſeful, that *Ariſtotle* ſays, that he who does not underſtand Motion well, muſt neceſſarily be ignorant of all natural Things.

13. That there can be no Diviſion without Motion.

the Workmen, who beat it as thin as they can, ſo that the Superficies of the Cylinder is thereby doubled.

6. *And therefore contains*) Multiply 12672, the Superficies of the Silver before it is beaten, by 680, and it will make 8616960.

7. *Which Superficies exceeds*) divide 8616960 by $26\frac{22}{29}$ and it will make 325795.

8. *Of half the Height*) Becauſe the Gold with which the Silver-Wire is covered was only half an Ounce, that is, half a Cube of Gold of an Ounce Weight.

CHAP. X.

Of Motion and Rest.

BECAUSE it is easier to understand what Motion is, by Experience, than to give a Definition of it, or to find out the Cause, I shall here make use of a familiar Example, agreed upon by all, which may serve to explain to us the Nature of Motion.

1. What it is to be moved. 1. Suppose a Man in a calm Day walking on Foot in a Park planted with Trees, and that at the Beginning he is observed to be between the first Trees in the Walk, and then between the Second, and so to continue on walking till he comes at the End; no Body doubts but the Man thus walking moves, and that every Step he takes is a real Motion. Consider now, that the Motion of this Man is something new, which was not in him before; and then if we take an exact Account of what we conceive to have come to him since he began to be moved, and reject every Thing which we certainly know is not Motion, we are sure that what remains, is, without doubt, the Thing we enquire after, and that this will show wherein Motion properly consists.

2. What Motion and Rest are. 2. Now because we do not acknowledge a *Vaccuum*, as *Democritus* and *Epicurus* did, therefore we cannot say with them, that this Man which we are speaking of, applies himself to different Parts of Space, because we do not distinguish Space from Matter as they did; wherefore in the Example now mentioned, there are three Things to be considered by us. First, The Desire of Walking in the Man: Secondly, The Effort he makes to put this Desire in Execution: And Thirdly, The Correspondence, or the *successive* Application of the external Parts of this Man, to the different Parts of the Bodies which encompass him, and immediately touch him. Now it is evident, that the Desire which this Man has, is not the Motion of him; for Desire is nothing but Thought, and we acknowledge many Things to be moved, which we do not allow to have any Thought. So likewise we ought not to think, that the Motion of the Man consists in the Effort which he makes towards Walking: For though we may truly say, that all Bodies which move, have an Effort (as we know they sometimes have, though they do not move) yet we are rather to think, that this Effort of the

the Cause of the Motion, and not the Motion it self. Nothing therefore remains but that *Motion consists in* 1 *the successive Application of a Body to the different Parts of those Bodies which are immediately about it*; whence it follows also, that the *Rest of a Body, is the continual Application of that Body to the same Parts of those Bodies which are about it and immediately touch it.*

D 4 3. It

1. *Successive Application of a Body*, &c.) The Dispute about the Nature and Definition of *Motion*, amongst the Writers of Philosophy, has always been very perplexed. I suppose, because, not sufficiently attending to the different Senses of an ambiguous Word, they endeavoured to comprehend *that* in one Definition, which ought to have been very exactly distinguished into its different Parts. That *Motion* (or rather the Effect of Motion) in general, *is a Translation of a Body from one Place to another*, is pretty well agreed amongst them all. But what is meant by *being translated from one place to another*, here the Controversy lies, and Philosophers differ widely. They who define Motion by comparing the Thing which is moved, not with the Bodies that encompass it, but only with Space which is immoveable and infinite, can never know or understand, whether any Body at all rests, nor what the absolute Celerity of those Bodies that are moved is; for besides, that this whole Globe of the Earth revolves about the Sun, it can never be known whether or no the Center of this whole System, in which all the Bodies relating to us is contained, rests, or is moved uniformly in a streight Line. Again, they who define Motion by comparing the Thing which is moved, not with infinite Space, but with other Bodies, and those at a very great Distance, these necessarily make some Body the Mark by which all Motion is to be measured; which, whether it self is at rest, or, with respect to Bodies at a still greater distance, is moved, is impossible to be known likewise. Lastly, They who define Motion by comparing the Thing which they say is moved, with distant Bodies, but only with that Superficies which immediately touches it; it is very weak in them to say, that those Things are truly at rest, which being connected with the Particulars of other Bodies, are moved with the greatest Swiftness; as the Globe of the Earth which is incompassed with Air, and revolves about the Sun. And on the contrary; that *they* only can be said to be moved, that with the utmost Force, and Resistance which they can make, can do no more than barely hinder themselves from being carried along with other Bodies, as Fishes which strive against the Stream.

But if we rightly distinguish the different Senses of the ambiguous Word, this whole Mist will immediately vanish. For a Thing in Motion, may be considered in three Respects; by comparing it with *the Parts of infinite and immoveable Space*, or with *Bodies that surround it at a distance*, or with *that Superficies which immediately touches it*. If these three Considerations be exactly distinguished into their several Parts, all future Disputes about Motion will be very easy. First then, a Thing in Motion may be compared with the Parts of *Space*: And, because the Parts of Space are infinite and immoveable, and cannot undergo any Changelike Matter; therefore that Change of Situation, which is made with respect to the Parts of Space, without any regard had to the Bodies, which encompass it, may rightly be called, *absolutely and truly proper Motion*. Secondly, a Thing in Motion may be compared with distant Bodies, and because it may in this manner be transferred along with other Bodies which immediately surround it; therefore that Change of Situation which is made with respect to those Bodies which are at a distance, and not to those which are near, may properly be called, *relatively common Motion*. Lastly, a Thing in Motion, may be compared with the Superficies of those Bodies which immediately touch it: And because, whatsoever is thus moved, may possibly have no *absolute* or

3. In order to determine whether a Body be in Motion or no, there is no need of comparing it with Bodies at a distance.

3. It is to be obferved here, that when we fpeak of Motion or Reft, we always mean an immediate Application, and have no Regard to the Relation a Body ftands in to Things at a diftance, any further than to confider fuch fort of Relation as a mere external Denomination only, which makes no Alteration in the Thing, and which is

or *common* Motion at all (as if an Arrow were fhot towards the Weft, with the fame Swiftnefs, that the Earth turns towards the Eaft;) and on the contrary, that which in this refpect is at reft, may really be transferred with both *abfolute* and *common* Motion (as Bodies hid in the Bowels of the Earth) therefore that Change of Situation which is made with refpect to thofe Superficies, which immediately touch the Thing moved, may rightly be called *Motion relatively proper*.

Firft, *Abfolutely and truly proper Motion*, is *the Application of a Body, to the different parts of infinite and immoveable Space*. And this is indeed alone abfolute and proper Motion, which is always generated and changed by the Forces impreffed upon the Body that is moved, and by them only; and to which alone are owing the real Forces of all Bodies to move other Bodies by their impulfe, and to which they are in proportion (*See Newt. Princip. Book I. Def.* 2,--8.) But this *only true Motion* cannot be found out or determined by us, nor can we diftinguifh, when two Bodies any way ftrike againft each other, which the *true Motion*, and confequently the true Force from whence that Impulfe arifes, belongs to; whether to that which feems to us to move fwifteft, or to that which moves floweft, or perhaps feems to be quite at reft; becaufe it cannot be demonftrated whether the Center of Gravity, as was faid before, or of the whole Syftem (which we may properly enough define to be, *One Point in Infinite Space*,) be at reft or no.

Secondly, *Motion relatively common* is *the Change of Situation which is made with refpect, not to thofe Bodies which are neareft, but to fome that are at a diftance*. And this fort of Motion we mean, when we fay, that Men, and Trees, and the Globe of the Earth it felf revolve about the Sun: And we mean this Motion alfo, when we confider the Quantity of Motion, or the Force of a Body in Motion to ftrike againft any Thing. For Example, when a Ball of Wood, with a piece of Lead in it to make it heavy, is thrown out of our Hand, we commonly reckon the Quantity of Motion, or the Force with which the Ball ftrikes, from the Celerity of the Ball, and the Weight of the included Lead together. I fay we *commonly* reckon it fo, and indeed truly, with refpect to the Force it felf, or any fenfible Effect of it; but whether that *Force or true Motion* be *really* in the Ball that ftrikes, or in the Earth which feems to be ftruck; this, as was faid before, we cannot certainly determine.

Laftly, *Motion relatively proper*, is *the fucceffive Application of a Body to the different Parts of Bodies which immediately touch it*. And this is the Motion we generally mean in Philofophical Difputes, where we enquire into the Nature of particular Things, as when we fay, that Heat or Sound, or Liquidnefs, confift in Motion. But particular Notice ought to be taken, that the *fucceffive Application of a Body*, is fo to be underftood, that it is to be applied fucceffively to the different Parts of the Bodies immediately touching it, *with its whole Superficies taken together* (*or tout ce qu'il a d'exterieur*, as the *French* expreffes it;) as when a Ball that is thrown, glides againft the different Parts of the Air with its whole Superficies; and when our Hand is moved up and down, it is fucceffively applied with its whole Superficies, to the different Parts of the Air on the one Side, and of the Joint by which it is faftned to the Body on the other Side. It was to no purpofe therefore for Mr. *Le Clerc* to find fault with this Definition, *Phyf. lib. 5. Chap. 5. It will follow*, fays he, *that the Banks and the Channel of the River are as much moved as the Water, becaufe they are as far removed from the Water*

is nothing real in the Subject under Confideration. Thus, the Man whom we fuppofe walking amongft the Trees, may alfo keep at the fame diftance from the fame Parts of the Water that runs in a Canal juft by, and yet we don't fay that he is *at reft*; and another Perfon fitting in the Walk, may be againft different Parts of the Water, and yet we don't fay that he *is in Motion*. Whence it follows, that they are very much miftaken, who, in order to determine whether a Body be at Reft, or in Motion, compare it with immoveable Parts which they imagine to be beyond

Water that runs by, as the Water is from the other Parts of the Channel and Banks. But the Cafe of the Water is very different from that of the Banks. The whole Superficies of the Water is fucceffively applied to different Parts of the Bodies which furround it, and immediately touch it, and therefore is transferred from fome of thofe furrounding Bodies to others. But the Banks are partly fixed to the Earth, and therefore are not transferred from thofe Bodies which immediately furround them. For when we fay, that a Body is transferred, we mean that the Whole of it is transferred. Wherefore an Ifland fticking up in the middle of a River, is not moved (not fo much as with this *mere relative Motion*) tho' the Water flides by it, becaufe it is firmly fixed in the Earth, and is not transferred from that which immediately touches it. So a Body equally poifed in a Liquor whofe Parts run npon it with equal Force, is not moved; becaufe though every particular Part of the Superficies of it be every Moment applied to different Parts of the Liquid that furrounds it, yet the whole Superficies of it is not transferred at once from the concave Superficies of the Parts which furround it, confidered as one whole Superficies.

Further, according to thefe different Definitions of *Motion*, are we to underftand the Word *Place* in different Senfes. For when we fpeak of *truly or abfolutely proper Motion* (or *Reft*;) then hy *Place* we mean, *that Part of infinite and immoveable Space which the Body poffeffes*; whereas when we fpeak of *Motion relatively common*, then by Place is meant, a *Part of fome particular Space or moveable Dimenfion*, which Place it felf is truly and properly moved, along with that which is placed in it: And when we fpeak of *Motion relatively proper* (which indeed is very improper) then by *Place*, is meant *the Superficies of the Bodies* (or *fenfible Spaces*) *which immediately furround the thing moved*. As to the Definition of *Reft*, all are very well agreed in it: But whether Reft be a mere *privation* of Motion, or *any Thing pofitive*, this is fharply difputed. *Cartes* and fome others contend, that That which is at Reft, has fome kind of Force, by which it continues at Reft, and whereby it refifts every Thing that would change its State; and that Motion may as well be called a Ceffation of Reft, as Reft is a Ceffation of Motion. *Malebranch in his Enquiry after Truth, Book 6. Chap. 9.* and others contend on the contrary, that Reft is a mere privation of Motion; their Arguments may be feen briefly explained in Mr. *Le Clerc's Phyf. Book 5. Chap. 5.* One Thing only I would obferve by the way, relating to this Matter; and that is, that *Malebranch* and Mr. *Le Clerc*, who follow his Opinion, in the following Argument, beg the Queftion. Suppofe, fay they, a Ball at reft; fuppofe that God fhould ceafe to will any Thing concerning it; what would he the Confequence? It would be at reft ftill. Suppofe it be in Motion; and that God fhould ceafe to Will that it fhould be in Motion, what would follow then? It would not be in Motion any longer. Why not? Becaufe the Force, whereby the Body in Motion continued in the State it was, is the *pofitive* Will of God, but that whereby it is at Reft is only *privative*: This is a manifeft begging of the Queftion. In reality, the *Force* or *Tendency* by which Bodies, whether

beyond the Heavens, where it is very uncertain, whether there be any Parts of Matter more immoveable than those near us.

4. A remarkable Instance of a Body in Motion and of another Body at Rest.

4. Having thus explained the Nature of Motion and Rest; when we see a Fish in the River keeping it self for some time right against the same Part of the Bank, and neither the Stream which surrounds it, carrying it downward, nor its own Force, by which it strives against the Stream, carrying it upward, we say that it is really *in Motion*, because it really agrees in every particular, with another in a Pond, which is by all allowed to be in Motion; for the Effort of the Former, makes it to be successively applied to the different Parts of the Running Stream, in the same manner, as the Effort of the Latter, makes it to be applied to different Parts of the Water in the Pond. On the contrary, when we see a Stake floating on the Water, and carried along with the Stream, we say that it is *at Rest*, because it is incompassed with the same Parts (which is the general Reason why we say a Body is at Rest) though at the same time, the Stake and the River together, are but one Thing in Motion.

5. That to resist some sort of Motion, is to move towards the contrary part.

5. When a Fish that moves it self in the manner now described, is not carried along with the Stream, we are used to say, that it resists the Stream; so when a Body by its Resistance, hinders it self from being carried along with another Body with which it is entirely surrounded, we may as well say, that it moves the contrary way.

6. That Motion and Rest are only Modes of existing, and are each of them but Accidents of Matter.

6. Because we cannot conceive any Application to different Parts, without supposing a Body so applied, so that Motion depends necessarily upon the Thing moved; therefore we are not to think that Motion is any real Being, but only a *Mode* of the Body in Motion; and so likewise, that Rest is only a Mode of the Body which is at Rest. Whence it follows, that *Motion* and *Rest* add nothing more to the Body in *Motion* or at *Rest*, than *Figure* does to a *figured* Body; and since a Body may either be moved

ther in *Motion* or at *Rest*, continue in the State in which they once are; is the *mere Inertia* of Matter; and therefore if it could be, that God should forbear willing at all; a Body that is once in Motion, would move on for ever, as well as a Body at Rest, continue at Rest for ever. And the Effect of this *Inertia* of Matter is this; that all Bodies resist in proportion to their Density; that is, to the Quantity of Matter contained in them; and every Body striking upon another with a *given Velocity* whether that other be greater or less, moves it in proportion to the Density or Quantity of Matter in this one, to the Density or Quantity of Matter in the other.

or

or not moved; we conclude, that Motion and Rest are only accidental to Matter.

7. How to determine the Quantity of Motion.

7. Motion has always been acknowledged to be a Species of Quantity, which is measured partly by the Length of the Line, which the Body in Motion runs; for Example, when a Body of a given Bigness, suppose *a Cubic Foot*, moves a given Space, suppose *sixty Foot*, we call this a determinate Quantity of Motion, and it is twice or thrice as much, if the same Body runs 120 or 180 Feet.

8. Another Way to measure the Quantity of Motion.

8. It is also partly measured [1] by the Quantity of Matter which moves together; For Example, If a Body of *two Cubic Feet* runs through a Line *sixty Foot long*, it has twice as much Motion, as a Body of one *Cubic Foot*, which runs through the same Line: For it is evident, that we ought to reckon as much Motion, in each half of the Body of two Feet, as in the whole Body of one Foot.

9. How two unequal Bodies may have equal Quantities of Motion.

9. Whence it follows manifestly; that in order for unequal Bodies to have equal Quantities of Motion, the Lines which they run through, ought to be in reciprocal Proportion to their Bulk. Thus, if one Body be three times as big as the other, the Line which it runs through, ought to be but a third Part of that of the other.

10. How two Bodies hung at the Ends of a Ballance may be in æquilibrio.

10. When two Bodies hung at the Ends of a Balance or Leaver, are to one another, in reciprocal Proportion to their Distances from the fixed Point; they must necessarily, when they are moved, describe Lines which are to each other, in reciprocal Proportion to their Bulks. For Example: if the Body A be three times as big as the Body B, and these Bodies be so fastned to the Ends of the Leaver AB, whose Point C is fixed, that the Distance BC be three times as much as the Distance AC, the Leaver cannot incline either to the one Side or the Other, but the Space BE along which the lesser Body is moved, will be three times as much as the Space AD along which the greater Body is moved; wherefore the Motion of the

Tab.I. Fig. 3.

1. *By the Quantity of Matter*) That is, of the Matter which belongs properly to the Body in Motion; For, the subtile Matter, if there be any such thing, with which the small Pores of terrestrial Bodies are filled, is not transferred along with them, with the same common Motion; Therefore if a Ball of Iron, and a Ball of Wood of the same Bigness be moved with the same Celerity, there will be more Motion in the Ball of Iron, than in that of Wood. So likewise, if two equal leaden Balls, the one solid, the other hollow and empty, be moved with the same Celerity; the solid Ball will have more Motion than the hollow One, and will strike a Body against which it is thrown with greater Force. And the Quantity of Matter which is properly contained in any Body is to be determined by its Weight. Wherefore the Quantity of Motion is not to be measured by the Celerity and Bigness, but by the Celerity and Weight of the Body in Motion; which is carefully to be observed.

one

one Body, will be exactly equal to the Motion of the Other. This being so, there is no Reason to think, that the Body A, with four Degrees, suppose, of Motion downwards, should lift up the Body B with four Degrees of Motion, rather than the Body B with four Degrees of Motion tending downwards also, should lift up the Body A with four Degrees of Motion; wherefore we ought to think that they will be in *æquilibrio*. 1 And this is the Foundation of *Mechanicks*.

11. *The Reason why Liquors ballance each other.* 11. So likewise when any heavy Liquor is contained in an inverted Siphon, whose Tubes are wider one than the other; if we imagine the Height of the Liquor in each Tube to be divided into a great many equally thin Planes, one of these Planes in either Tube, cannot by sinking, raise the Liquor in the other Tube, but the Sinking and the Rising must be in reciprocal Proportion of the Quantity of Parts which sink to those which rise. Thus, if Tab. I. Fig. 4. the Width of the Part AB, the larger Tube of the Siphon ABCD, be a hundred times as much as the Width of the Part C, the straiter Tube; and consequently, the Quantity of the Parts of the Liquor in the Plane AB, a hundred times as many as the Quantity of Parts in the Plane C; then the Rising or Sinking of the Parts on the Side AB, will be to the Rising and Sinking of the Parts on the Side C, in a centuple reciprocal Proportion: Wherefore the Motion of all the Parts in the Tube AB is exactly equal to the Motion of all the Parts of the Tube C. So that they in the one, are no more able by sinking, to raise those in the other, than these Latter are able by sinking to raise the Former. Whence it follows, that if each Tube be divided into an equal Number of Planes, that is, if the Liquor be of an equal Height in them both, 1 it must keep it self in *æquilibrio*, unless disturbed by some external Cause.

12. Since

1. *And this is the Foundation of Mechanicks*) Upon this is built that famous Problem of *Archimides*, Δὸς πȣ̃ σῶ ϛ τὴν γῆν κινήσω, *To move a given Weight with a given Force*: For by increasing the Distance CB, the Force of the Body B may be increased infinitely. Tab. I. Fig. 3. For the manner how this is done by increasing the Number of *Leavers*, *Wheles*, *Pulleys*, *Screws*, &c. See *Wilkins's Mathematical Magick*, and others. The Force of every one of which *Mechanick Powers*, and whence it arises, fully explained below in the Notes on the 14*th Chap. Artic.* 9.

1. *It must keep it self in* æquilibrio.) Hence it follows, *That all Liquors press upon Bodies that are under them, according to their perpendicular Height, and not according to their Breadth.* Tab. XVII. Fig. ... Which Paradox may also be demonstrated in the following Manner. Let ABCDFE be a Vessel filled with Water: Now because the Culumn BF is heavier than the Column HG, it is manifest, that if the Vessel were open at H, the Column GH would rise till it became

12. That God is the first Mover.

12. Since it is only the Eſſential Properties of any Subject, which can be deduced from the Eſſence of it, after it is known; it is to no Purpoſe for us to endeavour to find out how Motion could be firſt produced in Bodies, becauſe this is not an eſſential Property; we ſhall not therefore ſtand to argue upon this Subject: But as we own God to be the Creator of Matter, ſo likewiſe we own him to be the firſt Mover of it.

became in *æquilibrio* with the Column B F. Since therefore the Cover which ſhuts up the Veſſel at H, hinders the Column GH from riſing, it is evident, that the Water at H preſſes the Cover of the Veſſel upwards with a Force equal to the Weight of BL; and becauſe all Preſſure is reciprocal, it is evident alſo, that the Water at G preſſes the Bottom of the Veſſel downwards with the ſame Force; to which Force the Weight of the Column G H is to be added, by which means, the Force of the Water preſſing upon G, will be the ſame as if the Column GH were equal in height to the Column FB, that is, as if it were filled up to M. The ſame may be demonſtrated likewiſe of all the other Columns; whence it is manifeſt, that the Bottom E D is preſſed in the ſame manne[illegible] as if the Veſſel, every where of equal [illegible]ickneſs, were filled with Water to N O.

But the Truth of this Demonſtration depends upon this Suppoſition, that the Liquor contained in the Veſſel he ſuch as cannot be compreſſed: as Water which cannot be compreſſed. What therefore was ſaid *of all Liquors*, is to be underſtood of ſuch *Liquors*, viz. that they *preſs upon Bodies that are under them, according to their perpendicular Height, and not according to their Breadth.*

Corol. 1. If the Tube A B be ſ[illegible]ped cloſe with a Cover, and [illegible] little Tube C D he f[illegible] with Water up to [illegible] the Water contained [illegible] this Tube, will preſs [illegible]n the Water below in the gre[illegible]ube, and this Preſſure will [illegible]ule it ſelf through all the W[illegible], and thruſt againſt the Sides [illegible] Cover of the Veſſel thus cloſed; and if a Hole be made in the Cover, for the Water to get out at, it will fly out thence with as much For[illegible] as if the little Tube C D were [illegible]s broad as the Tube A B. Tab. I. Fig. 4.

Corol. 2. If two Cylinders be exactly fitted to the Tubes AB, C D, Weights laid upon them will be in *æquilibrio*, if they are *in proportion* to the Width of the Tubes. For Example, if the Tube AB be four times as wide as the Tube CD, one pound Weight laid upon the little Cylinder, will he equal to the Force of four Pound Weight laid upon the great Cylinder; which Experiments may be infinitely diverſifyed. Tab. I. Fig. 4.

Corol. 3. Hence it is eaſy to explain that Paradox, which ſo much perplexed the Famous Dr. *Henry Moor*, and other learned Men, *viz.* why a flat round Board, ſuch as a Trencher, when it is put into Water, ſhould riſe up immediately, though the Weight of the incumbent Water be much greater, than that under it, and yet there be no ſuch Thing in Nature as Lightneſs to lift it up. Let ABCD be a Veſſel full of Water, F a round Board immerſed in the Water. Now becauſe, from what has been already ſaid, the Columns of Water H*b*, H*b*, communicate all their Weight to the Column *d d*, and, if the Column *d d* ſhould deſcend, the Column H*b*, H*b* would aſcend with a Celerity, proportionably greater, as they are leſs thick; whence it is evident, that theſe ought to be in *æquilibrio* with each other (in the ſame manner as in the Siphon, *Tab.* I. *Fig.* 4.) if the Column *d d* he all Water. But becauſe part of this Column is not Water, but the Board F, which is *ſpecifically* leſs heavy than Water; therefore the *æquilibrium* is altered, and the Column GG*dd* having leſs Force (compounded of the Magnitude and Velocity) than the Columns H*b*, H*b*; it muſt riſe ſo far, that there muſt be as much of the Wood Tab. XVII. Fig. 2.

above

13. That it is sufficient to allow, that God once created Motion.

13. But because it is not the Part of a Philosopher to make him working Miracles every Moment, and to have perpetual Recourse to his Power, we shall take it for granted, that when he created the Matter of this World, he impressed a certain Quantity of Motion upon the Parts of it, and that afterwards, by the common Course of his Providence, he hindred Things from returning into their original *Nothing*, and preserved always 1 the same Quantity of Motion; so that what remains for us to do, is only to enquire into other Circumstances of Motion, and to examine Second or Natural Causes.

above the Superficies of the Water, as it exceeds in Bigness a Quantity of Water of equal Weight If the round Trencher F were so exactly fitted to the Width of the Vessel, that no Water could get between it and the Sides of the Vessel, so as to communicate its Weight to the Water below, and by that means force the Board upwards; or if the Board touched the Bottom of the Vessel so close, that no Water could get in between it and the Bottom, then the Board would not rise at all. As I have often tried in Quicksilver, which does not wet the Board, and therefore will easily let it go close to the Bottom of the Vessel.

1. *The same Quantity of Motion*) *Some other Principle* (beside the Inertia of Matter) *was necessary for putting Bodies into Motion; and now they are in Motion, some other Principle is necessary for conserving the Motion. For if two Globes joined by a slender Rod, revolve about their common Center of Gravity with an uniform Motion, while that Center moves on uniformly in a right Line drawn in the Plane of the circular Motion; The Sum of the Motions of the two Globes, as often as the Globes are in the right Line described by their common Center of Gravity, will be bigger than the Sum of their Motions, when they are in a Line perpendicular to that right Line. By this Instance it appears, that Motion may be got or lost. By reason of the Tenacity of Fluids, and Attrition of their Parts, and the Weakness of Elasticity in Solids, Motion is much more apt to be lost than got, and is always upon the Decay. For Bodies which are either absolutely hard, or so soft, as to be void of Elasticity, will not rebound from one another. Impenetrability makes them only stop. If two equal Bodies meet directly* in Vacuo, *they will by the Laws of Motion stop where they meet, and lose all their Motion, and remain in Rest, unless they be elastick, and receive new Motion from their Spring. If they have so much Elasticity as suffices to make them rebound, with a quarter, or half, or three quarters of the Force with which they come together, they will lose three Quarters, or Half, or a Quarter of their Motion. And this may be tried, by letting two equal Pendulums fall against one another from equal Heights. If the Pendulums be of Lead or soft Clay, they will lose all, or almost all their Motions: If of elastick Bodies, they will lose all but what they recover from their Elasticity.* Newton's Opticks the 2d Edition, in *English*, p 373.

If it be asked how Motion, which is thus perpetually lost, should be perpetually regained. The Answer is; That it is regained by certain active Principles, *such as are* the Cause of Gravity, *by which Planets and Comets keep their Motions in their Orbs, and Bodies acquire great Motion in falling*. The Cause of Fermentation, *by which the Heart and Blood of Animals are kept in perpetual Motion and Heat: the inward Parts of the Earth are constantly warmed, and in some Places grow very hot. Bodies burn and shine, Mountains take Fire, the Caverns of the Earth are blown up; and the Sun continues violently hot and lucid, and warms all Things by his Light*; (and the Cause of Elasticity whereby Bodies restore themselves to their former Figures; all which Causes shall be treated of in their proper Places) *For we meet with very little Motion in the World besides what is owing to these active Principles*. Ibid. p. 375.

CHAP. XI.

Of the Continuation and Cessation of Motion.

1. That a Body at Rest, can never of it self begin to move, nor a Body in Motion of it self cease to move.

HOW it comes to pass that a Body in Motion, should continue to be moved, is one of the most considerable Questions relating to Motion, and has very much perplexed the Skill of Philosophers; but upon our Principles, it is not difficult to account for it: For, as was before observed, nothing tends to the Destruction of it self, and it is one of the Laws of Nature, *that all Things will continue in the State they once are* unless any external Cause interposes; thus that which exists to Day, will endeavour, as far as it can, to exist always; and on the contrary, that which has no Existence, will endeavour, if I may so speak, never to exist; for it never will exist of it self, if it be not produced by some external Cause: So also, that which is now a Square, will, as far as is in its Power, always continue a Square. And as that which is at Rest, will never of it self begin to move, unless something move it; so that which is once in Motion, will never of its self cease to move, unless it meets with something that retards or stops its Motion. And this is the true Reason why a Stone continues to move after it is out of the Hand of him that throws it,

2. That it is a mistake to think that Bodies in Motion do of themselves tend to Rest.

2. We shall therefore have but little regard to that common Saying of *Aristotle*'s, *That every Thing in Motion tends to Rest*, because there is no good Reason for it. For if this Opinion seems to have some Foundation from what we experience on the one Hand of the Things on the Earth, where a Stone or any other Body in Motion does not continue always to move; yet it is overthrown by what is observed on the other Hand in the Heavens, where from the Observation of many thousand Years, we find no Diminution of Motion.

3. That Aristotle's Opinion cannot be proved by Experience.

3. To which we may add, that this Opinion is not so easily supported, by the Experience of what is done here upon the Earth, as is imagined: For though indeed it be very evident, that we see the Bodies which were in Motion, cease to move, and to be at perfect Rest; yet it is by no means evident, that they tend to this of themselves: For no Body can ever think, that a Cannon-Ball, after it has entered three or four Foot into a Wall, has an Inclination after that to be at Rest. On the contrary, when

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we perceive that this Ball enters deeper or leſs deep, according to the Difference of the Bodies that receive the Force of it, we aſcribe, with more Reaſon, the Ceſſation of its Motion to the greater or leſs Reſiſtance made by thoſe Bodies.

4. That the Air reſiſts Motion, and that the Reſiſtance of Bodies is the Cauſe of other Bodies ceaſing to move.

4. This Opinion was peculiar to *Ariſtotle*, and no Body would have ever come into it, if they had conſidered, that Air, though it does not reſiſt Motion ſo much as a Wall, yet it makes ſome Reſiſtance, as we experience in a Fan moved quick; for then when they had ſeen a Cannon-Ball or a Stone, not always continuing to move in the Air, they would have thought, that this was cauſed by the Reſiſtance which the Air makes to the Motion of the Ball, and that the Ball loſes as much Motion as it communicates to the Air.

5. That a Body in Motion, loſes ſo much of its own motion as it communicates to other Bodies.

5. Now in order to find out how much of its Motion a Body loſes when it ſtrikes againſt other Bodies, you muſt remember, that we ſuppoſed [1] that God created a certain Quantity of Motion, and that by the common Courſe of his Providence, he preſerves as much Motion in Matter, as he impreſſed upon it at the Beginning; whence it follows, that if a Body in Motion, ſtrikes directly upon another Body at Reſt, and puſhes it before it, it muſt neceſſarily loſe as much of its own Motion, as it communicates to the other, in order for them to go on together with the ſame Celerity as if the two Bodies were one common Maſs. Wherefore if a Body in Motion be three times as big as the Body at Reſt, it will loſe a fourth Part of its Motion; and inſtead of running, ſuppoſe, a Line of four Fathom, in a given time, it will run but a Line of three Fathom; that is, it will move with a fourth Part leſs Celerity, than it did before.

6 That a Body in motion loſes leſs of its motion, when it ſtrikes againſt another Body already in motion, than when it ſtrikes upon a Body at Reſt.

6. If a Body in Motion, ſtrikes upon another Body in Motion alſo, it will make that move ſwifter; but it will not loſe ſo much of its own Motion, as if this latter had been wholly at Reſt; becauſe all that it has to do, is only to add ſome Degrees of Motion to thoſe it has already, in order to make the Bodies move with the ſame Celerity: One Example will make this clear. Suppoſe a Body to have a certain Quantity of Motion, for inſtance, twelve

1. *That God created a certain Quantity of Motion*) See above *Chap.* X. *Art.* 13. But though Motion may be deſtroyed, and hard Bodies that have no elaſtick Force, when they ſtrike againſt each other, are not reflected, but loſe their Motion; yet in other Caſes, Bodies perfectly hard, communicate their Motion to each other, according to thoſe Laws which the Author is explaining.

Degrees

Degrees, and that it ſtrikes upon another which is at Reſt; according to what was now ſaid, if the firſt Body be as big again as the other, it ought to communicate four Degrees of Motion to it, and keep eight to it ſelf. But if the Body which has twelve Degrees of Motion, ſtrikes againſt the other moving with three Degrees, it ought to increaſe its Motion but two Degrees, to make it have as much as it ought to have; becauſe this being but half as big as the other, it will by this means have Motion enough to go as ſwift as the other: And therefore that Body which before kept to it ſelf only eight Degrees of Motion, will now keep Ten. [1]

7. If

1. If a Body in Motion, be three times as big as another Body at Reſt, and ſtrikes againſt it with thirty two Degrees of Motion, it will give it eight Degrees of its Motion, and keep Twenty four to itſelf; But if the latter Body had four Degrees of Motion before, it will give it but five Degrees, and keep twenty Seven. By the ſame way of Reaſoning, it is eaſy to find out other Laws of communicating Motion in Bodies that are perfectly hard. But becauſe the hardeſt Bodies of all have alſo an *Elaſtick Force*, and becauſe the Caſe of Elaſtick Bodies, is different from this, and more difficult, you may find the Principal Laws by which their Motion is communicated, explained by theſe learned Perſons; Sir *Chriſtopher VVren*, Dr. *VVallis*, Mr. *Hugens*, in his Philoſophical Tranſactions, Numb. 43, and 46, and more fully by the ſame Mr *Hugens* in his Poſthumous Works, and by Mr. *Marriot*, in a whole Book wrote upon this Subject; and alſo very fully by Dr. *Keil* in his Lectures upon Natural Philoſophy. But this whole Matter may be comprehended in the following

PROBLEM.

The Weights and Velocities with which two Spherical Bodies, perfectly Elaſtick, whoſe Centers are moved in the ſame ſtreight Line, meet each other, being given; to find their Velocities after they have met.

In the following Computation, the Motion of Elaſtick Bodies after ſtriking againſt each other, is ſuppoſed to ariſe from two Cauſes.

I. From ſimple Impulſe. By the Force of which alone, if the Bodies had no Elaſtick Force, each Body after they had met, would either wholly reſt, *viz.* if they meet each other with equal Motion; or they would go both on together, as if they were united into one Body, with the ſame Velocity; and the Sum of their Motions (if they moved both the ſame Way) or the Difference of their Motions (if they moved contrary Ways) would continue the ſame after their meeting as before.

II. From *Elaſtick Force*. Which in Bodies perfectly Elaſtick, is equal to the Force with which they are compreſſed; that is, when two ſuch Bodies are ſtruck againſt each other, it is equivalent to that Motion which either of them would gain or loſe by ſimple Impulſe only. This Force acts the contrary way, and therefore the Motion which is produced by it, muſt be ſubſtracted from that Motion, which is in the Body impelling, and added to that Motion which is in the Body impelled by the Force of ſimple Impulſe only, in order to find their Velocities after Reflection.

This being ſuppoſed. Let A and B be two perfectly Elaſtick Bodies, and let A either overtake B, or meet it; Let their Velocities be a and b; Then the Motion of A will be Aa, and the Motion of B, will be Bb, and the Quantity of Motion, in them both together, if they be moved the ſame or contrary ways will be Aa $\pm$ Bb, which (by the 1ſt *Poſition*) will be the ſame after their Impulſe as before. Now (if they had no Elaſtick Force) their common Velo-

7. *How a Body loses its Motion.* 7. If a Body which was moved by another, be by any Means turned out of the Way, so that That from which it received its Motion, is left to move freely, it will continue only to move as it did after it had moved the other, and

city after they had met, would be $\frac{Aa \pm Bb}{A + B}$; and therefore the Motion of A, would be $\frac{A^2a \pm ABb}{A + B}$, and that of B, $\frac{ABa \pm B_2h}{A + B}$. Now if the Motion $\frac{A_2a \pm ABh}{A + B}$, which remains in A after the Impulse, be substracted from the Motion Aa, which it had at first, there will remain the Motion $\frac{ABa \mp ABh}{A + B}$, which the Body A has lost by Simple Impulse only. Now if this Motion be substracted from the Motion $\frac{A_2a \pm ABb}{A + B}$ which is in A, and added to the Motion $\frac{ABa \pm B_2b}{A + B}$ which is in B after their Meeting, from the first Cause only; the Remainder $\frac{A_2a \pm 2ABb - ABa}{A + B}$ will (by the second *Position*) be the Motion of A; and the Sum $\frac{2ABa \pm B^2b \mp ABb}{A + B}$ will be the Motion of B, from both Causes together, after Reflection. And by dividing separately these Motions by their Bodies, we shall have $\frac{Aa \pm 2Bh - Ba}{A + B}$ for the Velocity of A, and $\frac{2Aa \pm Bb \mp Ah}{A + B}$ for the Velocity of B after Reflection. Q. E. J. (See *Newt. Algebra. Pag.* 91. *Probl.* 12.)

N. B. It may so happen, that the Body A, whether it overtakes B, or meets it, may lose all its Motion, or may be driven back the contrary way to that it moved in before they met. Wherefore in this Case the Quantity $\frac{Aa \mp 2Bb - Ba}{A + B}$ by which the Velocity after Reflection is expressed, will either become Nothing (the Negative and Positive Terms destroying one another) or Negative. So likewise it may happen, that when the Body B meets A, it may, after their Meeting, either rest, or go on to be moved the contrary way to that A was moved in, before they met; and then the Quantity by which the Velocity is expressed, will either be Nothing, or (as at first) Negative. But if it be driven back the same way that A was moved in at first, the Quantity by which the Velocity is expressed, will be positive. For since the Velocity that way which A was at first moved in, is expressed by the Sign +; 'tis evident, that the Velocity the contrary way, ought to be expressed by the contrary Sign − throughout the whole Computation.

From these general Quantities now found, by which the Velocities of the Bodies A and B are expressed, it is easy to deduce the Laws of Motion which are observed by any perfectly Elastick Bodies after Reflection, in any given Case whatsoever. For Example.

1. If the Velocities of two Bodies meeting each other, be reciprocally as their Weights, in this Case it will be $Aa = Bb$, and therefore the Quantity by which the Velocity of A is expressed, $= \frac{-Aa - Ba}{A + B} = -a$; and that of B, $= \frac{Ah + Bh}{A + b} = b$. That is, each Body after their Impulse, will go back with the same Velocity with which they met each other.

2. If A strikes against B, when it is at rest, the Velocity of A will be (the Quantity B, and consequently its Multiples, &c. vanishing) $= \frac{Aa - Ba}{A + B}$, and the Velocity of B will be $= \frac{2Aa}{A + B}$. That is, as the Sum of their Bodies is to their Difference, so is the Velocity of the Body A before Reflection, to its Velocity after Reflection. And as the Sum of the Bodies, to double the impelling Body, so is the Velocity of A before Reflection, to the Velocity of B after Reflection.

3. If

and not as it moved before it communicated any of its Motion; becauſe the Manner in which any Thing ought to continue to exiſt, and to preſerve it ſelf, is that which it has this very Moment, and not that which it had ſome

3. If A be equal to B, and ſtrikes againſt it when it is at Reſt, the Velocity of A will be $= 0$. And the Velocity of B will be $= a$. Which ſhows that the Body A after ſtriking, will be at Reſt, and the Body B will be moved with the ſame Celerity after the Impulſe, that A was moved with before the Impulſe.

4. If A and B be equal, and meet each other with unequal Velocity, the Velocity of A after meeting will be $= -b$; and the Velocity of $B = a$. That is, each of them will return back after meeting, having changed their Velocity.

5. If A and B be equal, and A overtakes B, the Velocity of A will be $= b$, and the Velocity of $B = a$. That is, they will both move the ſame way they did before, having changed their Velocity.

LEMMA.

If there be three unequal Quantities A, B, C; and A be leſs than B, and B leſs than C. I ſay, (1.) that $B + \frac{AC}{B}$ is leſs than $A + C$ (2.) that $B + \frac{AC}{B}$ is leaſt of all, when B is a mean proportional between A and C.

DEMONST.

The firſt part is evident from Prop. 25. *Book 5. of Euclid.* The *Second* Part may be demonſtrated thus. Let M be a mean proportional between A and C: then $M^2 = AC$. Now if M and B be equal, it is $B + \frac{AC}{B} = 2M$ or $2B$. But if there be any difference between M and B, let that difference be D; and it will be $M \pm D + \frac{M^2}{M \pm D} = B + \frac{AC}{B}$. But $M \pm D + \frac{M^2}{M \pm D}$ is greater than $2M$ as is evident by multiplying each of them by $M \pm D$ and comparing their Products together. Therefore, *&c.* Q. E. D.

(6.) Let there be three Elaſtick Bodies, as mentioned in the Lemma, A, B, C; and let A ſtrike againſt B at reſt; and after that, let B ſtrike againſt C at reſt alſo; I ſay, that by this Means, the Body C will acquire greater Velocity, than if it had been ſtruck immediately by A alone, without the Interpoſition of B; and that it then acquires the greateſt Velocity, when B is a mean Proportional between A and C. (And the ſame holds true, if the Motion begins with the Body C.)

For by the *Second* Law, explained above, the Velocity of C, if it were impelled by A only, and the Body B not between them, will be $\frac{2Aa}{A+C}$ or $\frac{4Aa}{2A+2C}$. And by the ſame Law, the Velocity of C, when ſtruck by the Body B with that Motion which was given it by A, will be $\frac{4Aa}{A + C + B + \frac{AC}{B}}$, which two Fractions, becauſe they have the ſame common Numerator ($4Aa$) are to one another as their Denominators, inverſely. Wherefore the Velocity of C in the firſt Caſe, is to its Velocity in the Second, as $A + C + B + \frac{AC}{B}$ to $2A + 2C$. But (*by the Lemma*) $B + \frac{AC}{B}$ is leſs than $A + C$, and leaſt of all when A, B, and C are in continual Proportion. Therefore $A + C + B + \frac{AC}{B}$ is leſs than $2A + 2C$. That is, the Velocity of C, in the firſt Caſe, is leſs than its Velocity in the Second, and this Inequality is greateſt, when A, B and C, are in continual Proportion. If the Motion begins at the Body C, than if c repreſents its Celerity, and be ſubſtituted in the Room of a, the Demonſtration will be the ſame.

7. The

Time before, but has not now. Wherefore a Body which has loſt ſome of its Motion, by meeting Another, may loſe more of it by a ſecond Meeting, or a Third, and ſo on, 'till at laſt it may be quite ſtopped, as we often ſee.

8. That greater Bodies continue to move longer than leſſer ones.

8. From what has been ſaid, it follows firſt, that if two like and unequal Bodies, be moved in a ſtreight Line with the ſame Celerity, 1 *the Greater Body ought to move longer than the leſſer*, becauſe, the Quantity of Motion in each of theſe Bodies, is in proportion to their Maſſes, but they communicate and loſe their Motion in proportion to their Superficies only, with which they ſtrike againſt other Bodies, amongſt which they are moved; now though the *bigger* Body has more Superficies than the *Leſſer*, yet it has not ſo much in proportion to its Bulk, and conſequently *it* does not loſe every Moment ſo much of its Motion as the *leſſer* one does.

9. An Example.

9. One Inſtance will make this clear. Suppoſe the Body A to be a Cube two Foot every Way, and the Body
Tab. I. Fig. 5. B, a Cube of one Foot; which being ſuppoſed, the Superficies of the Body A will be four times as much as the Superficies of the Body B, but the Maſs of it, will be eight times as big: And conſequently, if theſe Bodies move with the ſame Celerity, the Body A will have eight times

7. The more Bodies there are of a different Magnitude, between any two Bodies, ſo much the greater will the Velocity of the Laſt be: And it will be the greateſt of all, if the Bodies be in a continued Proportion. This eaſily follows from the preceding Article.

8. Perfectly elaſtick Bodies recede from each other after Reflection, with the ſame relative Velocity, that they approached each other with before Reflection; that is, in any given Time, the Diſtance between the two Bodies before, and after their meeting, will be the ſame, at the End of that time. For the diſtance of the Bodies in any given time, before they meet, may be expreſſed by $a \mp b$: *viz.* the ſame Quantities by which the difference of their Velocities, if they be moved the ſame way, or the Sum of their Velocities, if they be moved different Ways, is repreſented: Alſo the Spaces which they deſcribe ſeparately, in a given Time, after Reflection, may be expreſſed by the ſame Quantities, by which their Celerities are expreſſed; wherefore, if from the Quantity $\frac{2Aa \pm Bb \mp Ab}{A+B}$ which expreſſes the Space run through by the Body B after meeting, the ſame way that A moved before meeting, be ſubſtracted $\frac{Aa \pm 2Bb - Ab}{A+B}$ which expreſſes the Space run through by the Body A in the ſame time, and the ſame way; the Remainder $\frac{Aa \mp Ab + Ba \mp Bb}{A+B} = a \mp b$, will be the Diſtance of the two Bodies at the End of the given Time after Reflection.

And by the like Reaſoning other Laws may be found.

1. *The greater* [illegible] *ought to move longer*) It is to be obſerved, that this is ſaid of *Similar*, that is, *Homogeneous* Bodies. Otherwiſe we are to underſtand by it, not the Greateſt, but the heavieſt Body: For the Motion of Bodies that have the ſame Celerity, is not as the *Maſſes* of thoſe Bodies, but as the *Weights* of them. See the *Notes* Chap. x. Art. 8.

as

as much Motion as the Body B; ſo that it ought to loſe eight times as much every Moment, in order for them to ceaſe together. But this cannot be, becauſe the Body A, having but four times as much Superficies as the other, can meet with but four times as many Bodies, and not with eight times as many; wherefore the Body A will move pretty quick, when the Body B will have no Motion at all, as is confirmed by Experience; for if a Bullet and a ſmall Shot come at the ſame time out of a Gun, the Bullet will be carried vaſtly further than the ſmall Shot.

10. That a Body will continue to move longer, when it goes one way than when it goes another

10. *Secondly*, Hence it follows alſo, *That a long Body, ſuch as an Arrow, will continue to move longer, when it is ſhot lengthwiſe, than it would do if it went croſswiſe*, for it meets with fewer Bodies to transfer its Motion to, and therefore it keeps the more to it ſelf.

11. That a Body which moves almoſt within it ſelf, ought to continue its Motion longeſt of all.

11. *Thirdly, If a Body moves almoſt wholly within it ſelf*, ſo as to transfer very little of its Motion to the Bodies that ſurround it, *it ought to continue moving longeſt of all:* Thus we find by Experience, that a ſmooth well poliſhed Braſs Ball, of half a Foot Diameter, ſupported by two Pivots, will, with a ſmall Stroke, continue to run round for three or four Hours.

12. How a Body may ſeem to be wholly at Reſt.

12. But becauſe a Body cannot ſo transfer its Motion to another as not to partake with that Body to which it is transferred, but will retain ſome to it ſelf, though it be never ſo little; therefore it ſhould ſeem that a Body once in Motion, 1 ſhould never afterwards be entirely at reſt, which is contrary to Experience. But we ought to conſider, that two Bodies which have but very little Motion, may be ſo connected and adjuſted to each other, as to be *in a manner* at Reſt, which is all that Experience ſhows us.

13. That a Body in direct Motion makes other Bodies turn in a Circle, in order to take its Place.

13. Becauſe the World is full, a Body moving in a ſtreight Line, muſt of Neceſſity puſh another, and that a Third, but it ought not to go on thus infinitely; for ſome of thoſe which are thus puſhed, will be forced to turn out of the Way, in order to take the Place of that which was firſt moved, that being the only Place where they can go, and which is free for them: Wherefore when any Body is moved, 2 a certain Quantity of Matter muſt al-

1. *Should never afterwards be entirely at Reſt.*) This is falſe, becauſe built upon a falſe Foundation, viz. *that Motion cannot be deſtroyed.* See the Notes above, Chap. x. Art. 13.

2. *A certain Quantity of Matter.*) this is for the moſt part true, not becauſe the World is full, but becauſe the State of the Air, and other Fluids in which Bodies are moved, is ſuch, that when any Body is moved out of its Place, theſe, by reaſon of their Fluidity, immediately run into that Place.

ways necessarily be moved in the Form of a Ring or a Circle, or some way equivalent thereto.

14. *That this Motion in a Circle, is the Cause of many surprizing Motions.*

14. This Truth, though it was known long ago, yet Philosophers, for want of duly attending to it, and well weighing and considering its Consequences, have thought it impossible to account for all the Motions we see in Nature by Impulse alone, which is the only way that we can conceive clearly, by which one Body moves another by pushing it; and which so naturally follows from the Impenetrability of Matter, which all the World agree in. And this is the Reason why they introduced into their Philosophy Things, indeed very specious, such as *Attraction, Sympathy, Antipathy, the Fear of a* Vacuum, *&c.* but which, at the Bottom, are mere Chimera's, invented to make them appear to give a Reason of that which they did not all understand, and therefore ought not to be used in the better sort of Natural Philosophy.

15. *The Obscurity of the Words Attraction, Sympathy and Antipathy.*

15. For as to [1] *Attraction, Sympathy,* and *Antipathy,* they ought not to be allowed at all, by reason of their Ob-

1. *Attraction*) Since nothing acts at a Distance, that is, nothing can exert any Force in acting where it is not; it is evident, that Bodies (if we would speak properly) cannot at all move one another, but by Contact and Impulse. Wherefore *Attraction* and *Sympathy* and all *occult Qualities*, which are supposed to arise from the *Specifick Forms* of Things are justly to be rejected. Yet because, besides innumerable other Phænomena of Nature, that universal Gravitation of Matter, which shall be more fully handled afterwards, can by no means arise from the mutual Impulse of Bodies (because all Impulse must be in proportion to the Superficies, but Gravity is always in proportion to the Quantity of solid Matter, and therefore must of Necessity be ascribed to some Cause that penetrates the very inward Substance it self of solid Matter) therefore all such *Attraction*, is by all means to be allowed, as is not the Action of Matter at a Distance, but the Action of some immaterial Cause which perpetually moves and governs Matter by certain Laws. *Have not the small Particles of Bodies certain Powers, Virtues or Forces, by which they act at a distance, not only upon the Rays of Light for reflecting, refracting and inflecting them, but also upon one another for producing a great part of the Phænomena of Nature? For it is well known, that Bodies act one upon another by the* Attractions *of Gravity, Magnetism and Electricity; and these Instances shew the Tenour and Course of Nature, and make it not improbable but that there may be more* Attractive Powers *than these. How these* Attractions *may be performed, I do not here consider. What I call* Attraction *may be performed by* Impulse (not Bodily Impulse) *or by some other Means unknown to me. I use that Word here, to signify only in general any Force by which Bodies tend towards one another, whatsoever be the Cause. For we must learn from the Phænomena of Nature, what Bodies* attract *one another, and what are the Laws and Properties of the* Attraction, *before we inquire the Cause by which the* Attraction *is performed. The* Attractions *of Gravity, Magnetism and Electricity reach to very sensible Distances, and so have been observed by vulgar Eyes; and there may be others, which reach to so small Distances as hitherto escape Observation; and perhaps electrical* Attraction *may reach to such small Distances, even without being excited by Friction.* Newt. Opt. p. 350.

It seems to me farther, that these Particles (of Matter) *have not only*

a vis

Obscurity. That they are obscure, is very evident; for if we take a Loadstone, for Example, It is manifest to all the World, that to say it has an *attractive Vertue* or *a Sympathy* with the Iron, does not at all explain the Nature or the Properties of it. And as to the *Fear of a* Vacuum, I reserve the Notion of That to the following Chapter, where we shall compare the Reasoning of the Antients and our own together.

a vis Inertiæ, *accompanied with such passive Laws of Motion, as naturally result from that Force; but also that they are moved by certain active Principles, such as is that* (Attraction which we call the Attraction) *of Gravity, and that which causes Fermentation, and the Cohesion of Bodies. These Princ'ples I consider not as* occult Qualities *supposed to result from the* Specifick Forms *of Things, but as general Laws of Nature, by which the Things themselves are formed: Their Truth appearing to us by Phænomena though their Causes be not yet discovered. For these are manifest Qualities, and their Causes only are occult. And the* Aristotelians *gave the Name of* occult Qualities *not to manifest Qualities, but to such Qualities only as they supposed to lie hid in Bodies, and to be the unknown Causes of manifest Effects: Such as would be the Causes of Gravity, and of magnetick, and electrick Attractions, and of Fermentations, if we should suppose that these Forces or Actions arose from Qualities unknown to us, and uncapable of being discovered and made manifest. Such* occult Qualities *put a stop to the Improvement of natural Philosophy, and therefore of late Years have been rejected. To tell us that every Species of Things is endowed with* an occult Specifick Quality *by which it acts and produces manifest Effects, is to tell us nothing. But to derive two or three general Principles of Motion from Phænomena, and afterwards to tell us how the Properties and Actions of all corporeal Things follow from those manifest Principles, would be a very great Step in Philosophy, though the Causes of those Principles were not yet discovered: And therefore I scruple not to propose the Principles of Motion above-mentioned, they being of very general Extent, and leave their Causes to be found out.* Id. Ibid. p. 374.

— *We have the Authority of the oldest and most celebrated Philosophers of* Greece *and* Phœnicia, *who made* a Vacuum *and Atoms, and the* Gravity *of Atoms, the first Principles of their Philosophy; tacitly attributing* Gravity *to some other Cause than dense Matter. Later Philosophers banish the Considerations of such a Cause out of natural Philosophy, feigning Hypotheses for explaining all Things mechanically, referring other Causes to Metaphysicks. Whereas the main Business of Natural Philosophy is to argue from Phænomena without feigning Hypotheses, and to deduce Causes from Effects, till we come to the very First Cause, which certainly is not* Mechanical, *and not only to unfold the* Mechanism *of the World, but chiefly to resolve These and such like Questions,* &c. Id. Ibid. p. 343.

CHAP. XII.

Of such Motions as are commonly ascribed to the Fear of a Vacuum.

1. What was originally meant by the Fear of a Vacuum.

THERE is no Subject more capable of showing us the Difference betwixt true and false Philosophy, or at least betwixt Reasoning justly and not justly, than this. For we see manifestly, that the one leads us, if not to the Truth, yet to so great an Appearance of Truth, that the Mind acquiesces in it; but the other gives us only Words, which we can form no Idea's from. For Proof of This, Let us take for instance a *Syringe*, one End of which being put into the Water, and the Sucker drawn, let us hear how the Antients reasoned about it. First, They observed, that there could be no *Vacuum* in Nature; then they considered, that there would be one, if the Sucker were drawn, and no Water followed; whence they concluded, that the Water ought to enter in proportion to the drawing the Sucker; and hence they said the Water ascended, lest there should be a *Vacuum*.

2. How the Sense of this has been corrupted.

2. Afterwards, the Manner of the Expression was changed, without altering the Notion; and it was said, that the Water ascended, for *fear* there should be a *Vacuum* in Nature: And this Expression being equivocal, it was taken in a bad Sense; and as it is customary to carry Things to Extremity, the Word *Fear* was changed to *Horrour*; so that it was affirmed, that the Water ascended, out of the *Horrour* which Nature had of a *Vacuum*, as if Nature (in the Sense that Philosophers understand that Word) was capable of *Horrour*.

3. *The Fear of a* Vacuum in the latter Sense, is very ridiculous; wherefore I am apt to think that the Philosophers took it in the former Sense only: But what way so ever it be understood, it does by no means answer the Question; any more than it would, if any one should ask, how Wood came from very remote Parts to *Paris*, and it should be answered, it came *out of the Fear of Cold*; this is no Answer to the Question; because the *final* Cause is alledged instead of the *efficient* Cause, which was the Thing demanded.

4. How

4. However, if the Reafoning of the Antients were juft, and built upon a good Foundation, though it could not make us underftand how the Water afcends, that is, explain to us the *efficient* Caufe of fuch Afcent; yet it fhould prove, at leaft, that it ought to afcend; and their Reafoning fhould agree with Experience. And that you may fee that it is defective here alfo, it is to be obferved; that if the fole Reafon, why any Space is filled, is for *fear* there fhould be any *Vacuum* in Nature, and this makes the Water afcend; as this Reafon is always the fame, it will follow, that the Water ought always to afcend, fo long as the Sucker of the Syringe is drawing, be it never fo long; now Pumps being only long Syringes, they ought to raife up Water to any Height whatfoever; yet Experience fhews us, that we cannot by Pumps, raife it above One and thirty Feet and a half, after which, the Water ftops, and will not follow the Sucker. Whence we ought to conclude, that *the fear of a* Vacuum, taken in the moft favourable Senfe poffible, is not at all the Caufe of the Waters afcending, fince it does not agree with Experience.

4. That the Reafoning drawn from the Fear of a Vacuum, *does not fufficiently agree with Experience.*

5. Having feen the Defect of the Reafoning of the Antients, let us fee if we can fay any Thing better founded. And that I may not be guilty of the fame Fault, I fhall offer fome Particulars, which are very clear and intelligible to all the World, in order to draw fome certain and undoubted Confequences from a Foundation which cannot be contefted.

5. Various Suppofitions to explain this another way.

6. Let us fuppofe firft, That fome Body endeavours to draw the Sucker from the Bottom of the Syringe ABC, the Hollow of which it exactly fits, that the whole Syringe is in the Air, and that the Hole C is open: This being fuppofed, it is evident, that the Sucker D cannot be drawn towards E, but it will pufh the Air, which will pufh that beyond it, 'till as was faid above, it turns in the Lines here defcribed, or fome fuch like, in order to enter into the Place from whence the Sucker was drawn; whence it follows, that the Air was moved by a real Impulfe.

6. The firft Suppofition. Tab. I. Fig. 6.

7. Let us fuppofe Secondly, That the Hole at C, was ftopped, and that there were no Pores either in the Syringe or the Sucker; In this Cafe, I fay, [1] it would

7. The Second Suppofition.

1. *It would be impoffible*) This would indeed be true, if the World were full: But becaufe we have affirmed it to be otherwife; fo much Force only is required to draw the Sucker, as can lift the whole Weight of the incumbent Air. Nor need we here trouble our felves with any occult Pores or fubtile Matter.

be

be impoſſible to draw the Sucker, the leaſt that can be, becauſe the World being full, the Air which ought to puſh the Sucker, would have no Place to go to.

8. The Third Suppoſition.

8. On the other hand, Let us ſuppoſe, that the Syringe thus ſtopped, has Pores, though ſo very ſmall, as not to be perceived by our Senſes, and that amongſt the Particles of the Air, there are ſome ſo ſubtle, as to be able to enter theſe Pores. This being ſuppoſed, there is no Reaſon why the Sucker may not be drawn, though the Hole at the Bottom of the Syringe be ſtopped: For then the Sucker may make Room for it ſelf, by preſſing the groſſer parts of the Air, and by ſqueezing out the ſubtle Parts, which are forced to enter the Syringe.

9. That the greateſt Part of terreſtrial Bodies have Pores, and that the Air conſiſts of two Sorts of Particles.

9. In order to know whether the Sucker of the Syringe can be drawn when the Hole at the lower End is ſtopped; we muſt firſt know, whether the Syringe or the Sucker have any Pores in them or no; and after that, whether there be any Particles in the Air ſubtil enough to enter in at theſe Pores: For according to one or other of theſe Suppoſitions, will the Thing be poſſible or not poſſible. And becauſe neither of them can be determined by our Senſes or by Reaſon, and there being no Contradiction in either, it muſt be decided by Experience; now we find by Experience, that 1 if the Syringe be not too thick, we can draw the Sucker without much Difficulty; from whence it is evident, that there are Pores either in the Syringe, or in the Sucker, or rather in both of them; and that amongſt the groſs parts of the Air, there are ſome ſo fine, as to paſs through the Pores of moſt terreſtrial Bodies.

10. Another very conſiderable Experiment; and that the Air is weighty.

10. This Experiment helps us to another very conſiderable, which is, that if, after we have drawn the Sucker a little, we let it go again, it returns of it ſelf, and that with ſuch a Force, as to ſtrike againſt the Bottom of the Syringe; the Reaſon of which we ſhall ſee, if we remember that a Body never begins to move of it ſelf, if it be not puſhed by another which immediately touches it; now, if we obſerve, that there is nothing but the Air, that immediately touches the Sucker, we muſt think that it is the Air that cauſes this ſurprizing Motion; and conſidering

1. *If the Syringe be not too thick*) The Thickneſs of the Syringe ſignifies nothing (nor the occult Paſſages, nor the ſubtle Matter, as was ſaid on the *Article above*;) but the Thickneſs of the Sucker; which the greater it is, ſo much a Greater, and conſequently ſo much a heavier Column of Air muſt it ſuſtain. But the Author may be excuſed, if he means the *Bigneſs* of the whole Syringe.

ſidering that the Air always contains in it a great Quantity of the Particles of Water, and other terreſtrial Bodies, which though they be ſeparated from each other and diſperſed, yet do not loſe any of their Weight; (though we do not fully underſtand the particular Nature of the Air, nor in what its Weight conſiſts;) we ſhall make no Difficulty to aſſert; that the groſſer Air is heavy, and conſequently, that by its Weight, the Sucker is forced into the Syringe, from whence it ſqueezes out the ſubtil Matter through thoſe Pores which it ſelf entered in at.

11. But though the Air by its own Weight, preſſes chiefly donwards, yet this does not hinder, but that it may alſo preſs upwards, and force the Sucker of the inverted Syringe up into the Syringe; for the Column of Air which anſwers to the Bottom of the Sucker, is forced upwards by the Weight of thoſe Columns of Air which are on the ſides, in the ſame manner as the Water which is at the Bottom of a heavy laden Boat, is preſſed upwards againſt the Bottom which reſiſts it, by the Weight of the Water which is of conſiderable Height round the Sides.

11. That the Air by its Weight may preſs upwards.

12. When we once underſtand this Force of the Air to preſs upwards, we ſhall not at all wonder, that when we hold our Hand flat in the Air, we do not feel the Weight of [illegible]; that is, we do not perceive our Hand preſſed downwards, by the Weight of the Column of Air which is upon it. For this Column has no more Force to preſs it downwards, than the Column which is underneath has, to preſs it upwards.

12. Why we do not feel the Weight of the incumbent Air.

13. As to the Preſſure which is made all over the Body, when it is immerſed in a heavy Liquid; it is certain, that we ought not to perceive it, [1] though the Weight of the Liquid be very great, any more than we do the Preſſure of

13. Why we do not feel the Preſſure of the Air, and alſo why Divers do not feel the Weight of the Water.

1. *Though the Weight of the Li[illegible] be very great*) The Cauſe of [illegible] is excellently well explained [illegible] *Jo. Alph. Borellus, de Mot[illegible] Nat. a Gravitate factis.* [illegible] 29. *& ſeq.* After he had [illegible], that Sand in a very ſtrong [illegible]el, cannot any way be div[illegible] and that a Wedge will by n[illegible]eans enter into it; and alſo th[illegible] Water in a Bladder, equally com[illegible]ed on all Sides, can neither be ſtreightened nor bent, nor at all moved: *So likewiſe,* ſays he, *in the B[illegible]dy of an Animal, there is contained within the Skin, ſome Parts, which are hard and ſolid, ſuch as the Bones; others that are ſoft, ſuch as the Tendons, Nerves, Membranes and Muſcles; and others that are Fluid, Watry or Oily. Now the Bones in an Animal cannot be broken or disjointed, unleſs the incumbent Weight preſſes one Way only, as it does on Porters: But if the Preſſure diffuſes it ſelf all round, ſo as to preſs upwards and downwards, and ſideways, with equal Force, ſo that there be no part of the Skin but what is preſſed; then it is impoſſible, that any Thing ſhould be ſeparated or put out of the Way. The ſame may be ſaid of the Nerves and Muſcles which though they be ſoft, yet becauſe they conſiſt of ſtrong and tough Fibres, they can all ſupport one another, and reſiſt an univerſally*

of the Water, when in diving into the Sea, there are many Fathom of it over our Heads. The Reason of which is; that before we can feel the Weight of any Body, there must be some Alteration made in the Disposition of our Organs. But when the Air or Water have made all the Efforts they are capable of to press or thrust inwards the external and grosser Parts of our Body, and these Forces are counterballanced and put in *æquilibrio*, by the Resistance and Effort of the Fluids and moveable Parts within us, the Action of which we are insensible of; after this, I say, they can do no more, and consequently the State of our Body will not be changed, nor the Disposition of its Organs, to which they are so uniformly applied, and with such equal Forces, that no one single Part can move outwards, to give way for any other to be thrust inwards; and therefore the Effort which they continually make to press us inward, is rendred ineffectual.

universally diffused spharical Compression; the same may also be said of the Blood and other Humours of an Animal, which are of a watry Nature; for, as it is evident, that Water cannot be condensed, so likewise the Humours of an animal, contained in the Cavities of its Vessels, though they may be bruised by an Impulse made from one or a few particular Places, yet they can never be forced out of their Vessels, or torn asunder by an universal Compression every Way. So long therefore as the Solid, Tendinous, or Fleshy, or Liquid Parts, do not undergo any Separation, Contusion, nor are disjointed, nor their Situation at all changed; it is impossible, that any Pain or Uneasiness should follow in the Animal, which cannot arise from any other Cause, but separating that which is one continued Thing. Wherefore when Divers, &c.

And this is confirmed by what the famous Mr. *Boyle* observed, *in his Second Appendix to the Eleventh Hydrostatick Paradox*, viz. that a Tadpole, an Animal whose Flesh is very tender and soft, put into a Vessel half full of Water, so closed up, that the Air contained in it, being condensed eight times as much as in its natural State, pressed upon the Water as much, as if a Column of Water of Three hundred Feet in Height laid upon the Animal; moved it self notwithstanding, and swam about very quick, and found no Inconvenience, that could be perceived.

However, because in most Animals there is a great deal of Air, which may easily be compressed and condensed; therefore, though no particular Member is disjointed, when an Animal is immersed very deep in Water, yet must all of them necessarily be streightned and contracted, by the equal Weight and Pressure of the incumbent Water on all Sides, as the famous Mr. *Boyle* says, happened to the Tadpole in the forementioned Experiment.

Besides, those Animals, whose Lungs are so formed as to contain a great deal of thin Air and Breath in them, though the other Parts of them be not at all hurt, yet their Breasts must of necessity be streightned and contracted, in the same Manner, as the Cork is usually thrust into an empty Bottle, by the Weight of the Water, when it is sunk very deep. Therefore Men, whose Lungs are very large, when they dive very deep into the Sea, though they find no manner of Inconvenience in any other Part of their Bodies, yet they labour under a Difficulty of Breathing, and a Pain in their Breast (though they have Air enough conveyed to them to breathe.) And thus the famous Mr. *Boyle* tells us of a certain Diver, that when he walked at the Bottom of the Sea, the Blood flew out at his Nose and Eyes.

14. Let

14. Let us, in the fourth Place, Suppose the Sucker which is in the Syringe, as far as it can be thrust, to be drawn when the Hole C at the Bottom is in the Water; it should seem as if the Air which the Sucker that is drawn presses upon, ought to press upon the Water, and make it to rise in the Syringe, because it overtakes it, in the way which we supposed it to go, in order for it self to enter in, if the End of the Syringe had been in the Air, and not in the Water, and that it ought to ascend as far as the Sucker is drawn. But there is no Necessity that this should always happen; For having made it appear, that both the Syringe and the Sucker are full of Pores, and that the Air is full of Matter, subtle enough to pass through them; and also that the Water, by reason of its Weight ascends with greater Difficulty; the Sucker may possibly be drawn, and the Water not necessarily ascend, to fill the Syringe, because it was filled before with that subtil Matter, intermixed with the Air. However, Experience shows us, that the Water does ascend, and that the Syringe is filled with it, and not with the subtle Matter, at least to the Height of One and thirty Feet and a half, but no further. The Reason of which is, that the Air being heavy, presses upon the whole Superficies of the Water in which the End of the Syringe is immersed; and when the Sucker is drawn, the Water which answers to the Hole in the End, not being pressed by the incumbent Air, the Weight of that which presses upon the rest of the Surface, thrusts it up, and makes it ascend in the Syringe; in the same Manner, as the Water in a Pail is made to ascend up a Trunk, such as they shoot with, open at both Ends, and one End fixed in a Hole in a Trencher which exactly fits the whole Superficies; upon depressing the Trencher, the Water is forced up. In like Manner, the Moving of the Sucker, is the general Cause of the Entrance of some Matter into the Place which it leaves; but the Weight of the Air determines the particular Matter. *14. How the Water is drawn into the Syringe.*

15. Since we find by Experience, that the Sucker of a Syringe may be drawn, when the Hole at the End is stopped, this is sufficient to convince us, that the grosser Air is not of an infinite Weight; for if it was, it would be impossible to draw it; which being so, it is easy to foresee, that the Air by its Weight cannot raise the Water in a Syringe above a determinate Height; so that if, after this Height, we continue to draw the Sucker, the Syringe, instead of being filled with Water will be filled with subtle *15. That the Water in a Syringe ought to rise but to a certain Height, and that a Column of Air, weighs as much as a Column of One and thirty Feet and a half of Water of equal Thickness.*

Matter

Matter, as was before obferved in Pumps: And fince the Water always rifes to about the Height of Thirty one Feet and a half, above the Level in which the End of the Pumps is immerfed, we ought to conclude, that a Column of Water of this Height, weighs as much as a Column of Air of equal Thicknefs, which reaches to the upper Surface where the groffer Air terminates.

16. That we ought not to perceive the Weight of the Air that is drawn into the Syringe; but we ought to perceive that of the Water.

16. If the Sucker of the Syringe flips very eafily along the concave Surface, againft which it rubs, and if it had no Weight at all, the Air would very eafily be drawn in; becaufe there is juft as much Force to thruft it upwards, as there is Weight upon the Sucker to thruft it downwards: But if Water or any other heavy Liquor is to be raifed; there muft then be as much Force ufed, as is equal to the Weight of the Liquor to be raifed; becaufe the Liquor, tending downward, bears upon the Air, which preffes againft the Bottom of the Sucker, and takes off fo much of the Force it had to make it rife.

17. When a Tube filled with Water ought to empty it felf.

17. There may be many Confequences drawn from what has been faid of the Syringe, which if they be agreeable to Experience, are fo many Confirmations of the Truth of our Explication. For Proof hereof, let us fuppofe, for Example, that after having filled a Tube with Water, one End of which is ftopped with the Matter of which it is made (which they call *Hermetically fealed*) and the other, with the End of one's Finger, we put the End of the Tube which is ftopped with our Finger into a Veffel of Water, and then take our Finger away; This being fuppofed, if we confider that the Air, which preffes upon the Water in the Veffel, refifts the defcent of that which is in the Tube, we may forefee, that if the Tube be not above One and thirty Feet and a half long, it will not empty it felf at all; but if it be longer, the Water ought to defcend till there is One and thirty Feet and a half in the Tube, and then ftop, becaufe the Air has only Force enough to counterpoife fuch a Quantity: And this is agreeable to Experience.

18. That an inclined Tube ought to contain more Water than an upright one.

18. We here fuppofe, that the Tube, which is above Thirty one Feet and a half long is held upright, and does not incline one way or the other: For if it incline any way, then, becaufe the concave Surface of the Tube fuftains part of the Weight of the Water, for that Reafon, the Water will not have fo much Force to defcend as it has ordinarily; and fo the Air is able to fupport a greater Quantity than One and thirty Feet and a half in the

the Tube; that is to say, according to the *Laws of Mechanicks*, if the Water in the inclined Tube begins to descend, it will stop, when the upper Surface of it, is One and thirty Feet and a half perpendicularly above the Superficies of the Water in the Vessel; and so we find it does.

19. And it is remarkable, that if we make use of Tubes of different thicknesses, and Vessels of different breadth, there is no difference in the Height of Water contained in the Tubes: For since the Water which is in each Tube, possesses the Place of that Quantity of Air, which laid upon the same Part of the Superficies of the Water in the Vessel; it cannot but be in *æquilibrio* with the Air without, because, it weighs just as much as that whose Place it possesses. And thus it is in all Tubes whatsoever, the Water rises to the same height, which we see by Experience in a particular Tube, that it ought to rise to; for as these different Columns of Water are of the same height; if that, for Instance, which is four times as thick as another, weighs four times as much as that other; then the Column of Air, the Place of which this gross Column of Water possesses, weighs four times as much also.

19. That the Water ought to be of equal Height in Tubes of different Thickness.

20. Neither ought we to find any difference in the Height of the Water which is in the Tube, whether the Experiment be made in the open Air, or in a Chamber, provided there be a Window in it, or at least any Chink through which the Air can enter; for according to *the Laws of Mechanicks*, the Weight of the Air is just the same, whether it presses perpendicularly, or winding or oblique.

20. That there will be no Alteration made in the Height of the Water, if the Experiment be made in a Place that is shut up.

21. Neither ought there to be any Difference in this Height, if after the Experiment be made, the Room be entirely closed up; for though the Column of Air which supported it before, by pressing upon the Liquor in the Vessel, be now intercepted by the Ceiling, yet that part of the Column of Air which is below the Ceiling, presses as much upon this Liquor as it did, when it bore the Weight of the rest of the Column, because the Resistance of the Ceiling does as it were press upon it, and hinder it from expanding it self.

21. That the Height of the Water ought to be the same, though the Place in which the Experiment is made, be intirely closed up.

22. It is true, that if, before the Experiment be made, the Chamber be so exactly shut up, that the Air within has no Communication with that without, then the Liquor contained in the Tube ought not to descend quite so far; because as the Tube empties, and the Liquor in the Vessel rises, the Air which is in the Chamber cannot rise in Pro-

22. That the Height of the Water ought to be greater, if the Place had been entirely closed up before the Experiment was made.

Proportion: Confequently it muft be condenfed, and therefore will have force enough to fuftain a little more Liquor in the Tube; but this cannot be perceived unlefs it be a very little Place in which the Experiment is made.

23. That Quickfilver ought not to remain in the Tube, above the Height of Twenty feven Inches and a half.

23. From what has been faid, it is eafy to apprehend, that if inftead of Water, any other Liquor that is heavier or lighter be ufed, there will remain more or lefs of it in the Tube; fo that Mercury or Quickfilver, which is about fourteen times as heavy as Water, ought not to be fuftained by the Air, but to about Seven and twenty Inches and a half, which is very near a Fourteenth Part of the Height that Water is fuftained, and the reft of the Tube, how long foever it be, ought to be filled with fubtle Matter. And this is confirmed by Experience.

24. That Experiments are more eafily made with Quickfilver.

24. But that the Experiments may be more fenfible, the Tubes fhould be made of Glafs, becaufe that is tranfparent; And Quickfilver being fo heavy, that we are not obliged to have Tubes much longer than Twenty feven Inches and a half, their Smallnefs makes them more eafy to be managed, and to obferve a great many particulars, which it would be difficult to do in Tubes that are very long.

25. That there is no Vacuum in the Top of the Tube.

25. Firft then, This may give Occafion to thofe who believe the Poffibility of a *Vacuum* to obferve; *That there is no* Vacuum *in the Top of the Tube*, but the Place which is left by the Mercury, is filled by fome Matter, becaufe the vifible Objects behind the Tube, [1] affect our Eyes ftill, and are as plainly fenfible as they were before, which they could not do, if there were a *Vacuum*; becaufe their Action would be interrupted. And if the Eye were placed directly againft the Tube, we ought not to fee any more than in the Dark, or than if an opake Body were between; but we find it otherwife.

26. Another Proof.

26. To this we may add, that [2] *Nothing* or a *Vacuum* has no Properties, and that if we put the Top of the

1. *Affect our Eyes*) It don't at all follow, *that there is no* Vacuum *in the Top of the Tube*, becaufe the Space out of which the Quickfilver came, is tranfparent; For why cannot the Rays of Light, pafs through *an entirely void Space*? On the other Hand, they can't poffibly pafs through *a Space that is quite full*: See what is faid of the Nature of Light, in its Place.

2. *Nothing*, *or a* Vacuum *has no Properties*) [illegible] very true indeed that *Nothing* has no Properties; But how does it follow, that Space which is *void of Matter*, has therefore *Nothing* in it, or is it felf entirely *Nothing*. But it may be allowed that there is fome finer Matter in the Top of the Tube, or perhaps a little Air flipt under the Quickfilver which is rarefy'd by the Heat; but the Space is very far from being full.

Tube

Tube very near the Fire, we perceive a Rarefaction, in the same manner, as in a Thermometer, which makes the Mercury fall, whence it follows, that there is some real Matter in it.

27. However it is easy to see that this Space is not full of common Air; for if the Tube be not quite filled with Quicksilver, but an Inch or two be left for Air, and stopping the End of the Tube with our Finger, it be inverted; we observe that the Quicksilver descends slowly, and we have time to see the Air ascend in the Form of Drops. Whereas let the Tube be entirely filled with Quicksilver, and immersed in the other Quicksilver, that it may empty it self in the ordinary way; then if the Tube be stopped with the Finger and inverted; the Quicksilver will not fall slowly, but all at once, as if it were one hard Body, nor shall we perceive any Thing to ascend through it. *27. That the Top of the Tube is not full of gross Air.*

28. For a further Confirmation of this Opinion, *viz. That when the Quicksilver descends from the Top of the Tube, it is not filled with common gross Air*, we may observe; that if the Top of the Tube be made large, in the Form of a Vessel, and some Sort of Animals, as *Birds*, *Rats*, and *Mice*, be put into it, they will die, in a very short time; that others, such as Flies, seem to die, but being preserved afterwards, two or three Days in a more temperate Place they revive and fly away, and others, such as *Worms* and *Frogs* are preserved alive, and not hurt, unless they continue very long in it: *28. The Third Proof.*

29. It may here be demanded, how the subtil Matter, which fills the Top of the Tube, gets through: To which it may be answered; that it seems rather to pass through the Pores of the Glass, than those of the Quicksilver, because the Quicksilver being very heavy, the Pores of it seem to be rather too small for it to pass through them: Though I shall be of another Opinion, if what I have heard from *England* be true, *viz.* [1] that a Tube of six Foot long, will not empty it self at all, if the Quicksilver *29. What Pores the subtil Matter which is in the Top of the Tube may pass through.*

 ver

1. *That a Tube of six Foot long*) This Experiment is thus related by the famous Dr. Wallis in his *Hydrostaticks*, Prop. 13. *If the Quicksilver suspended in an inverted Tube, be very exactly cleared of all Air before it be inverted (which cannot be done but by great Care and Niceness,) and if the Tube be cautiously inverted, and fixed in a firm Place so as not to be in the least shaken; the Quicksilver (though the Orifice at the Bottom be open) will remain suspended, much beyond the forementioned Height* (viz. *to 40, 50, or 60 Inches;*) *but if the least Air gets into the Quicksilver thus suspended, or if the Tube be shaken, the Quicksilver will immediately rush down to the usual Height (and after some Reciprocations,) will stand still.*

Which Experiment, having been often repeated by the Lord *Brounker*, the famous Mr. *Boyl*, Mr. *Huygens* and others, has succeeded; so that there is no doubt of the certain Truth of

ver with which it is filled, and that in which it is immersed, have stood some time in a Place void of gross Air: For in inquiring into the Reason of this Phænomenon, we can find no other but this, that the Quicksilver thus prepared, is cleared of some Matter,

of the Phænomenon; but upon what Causes so surprizing a Thing depends, is not so well agreed.

The Lord *Brounker thought, that the Weight of the Air was much greater than answers to the Height of about 29 Inches of Quicksilver, but that the Quicksilver was depressed to that Height, by the Air which was invisibly mixed with it (unless it was cleared of it.) And after it was cleared of it, and there remained nothing to resist the Weight of the external Air, but only the bare weight of the Quicksilver, then it was found to be otherwise; and the Quicksilver was supported to a greater Height, by the Ballance of the Air.* This is indeed very ingenious; but that which weakens very much this Explication, is, that upon the least shaking of the Tube, the Quicksilver immediately rushes down: which could by no means be, if it were supported by an equal Weight of Air or Æther.

Wherefore the famous Dr. *Wallis* attempted the Thing another way. He imagined, *that all real Gravitation, proceeded from the Pressure or Spring of the Air or Æther, without which those inactive Bodies which we call heavy, if once at rest, would remain so, without any real gravitation, or without descending, having no more Tendency to move downwards than sideways. The Quicksilver therefore when it is cleared of all Air from within, and suspended in the aforesaid manner; when it is at rest, will continue so, and retain its Position, beyond the common Height necessary to an æquilibrium; because it is free from all Pressure of the Air, and is not pressed upon, either by its Gravity, or by its Spring: But if it be put in Motion, either by any shaking of the Tube, or by any Motion within, from the Spring of the Air which was at first left in it, or is since got in, then it will continue that Motion downwards (that way being open.)*

But since it is now allowed, that Gravity does not depend upon the Air or Æther, but is an original connate and immutable Affection of all Matter, neither can this Explication be admitted. And indeed this very learned Person confesses, that he himself was not satisfied with it. Therefore he adds, *That the Superficies of the Tube however well polished, cannot be thought to be so free from all Ruggedness or Inequality, but that there must remain some Roughness, which must cause Cohæsion, or (if it be moved) some Friction of the adjacent Body, whereby the Motion must be something hindred.*

And indeed this Opinion comes nearer the Truth; and that chiefly because upon the least shaking of the Tube, the Quicksilver falls down; whence it is manifest, that the Suspension does not depend upon any permanent Cause, such as the Gravity of the Air or Æther, but upon some accidental Thing, such as some kind of Adhesion. However, because there does not appear to be any such *Roughness* in the Superficies of the Glass, as this learned Person imagines; it seems to be most probable, that the Quicksilver remains thus suspended from *the Contact or Agreement of the Parts*, the Force of which is always very great in every Effect of Nature. Thus, a plain and smooth *Loadstone* applied to a Ball of Iron suspended on a String from a Nail, will draw it much further from the Perpendicular, than in proportion to the Magnetick Force; if it be pulled back with a gentle and even Hand, and be not separated by any accidental Shake. So also Water will ascend in a *Vacuum* in small Glass Tubes open at both Ends. And two smooth polished *Marbles* will not be separated, though the gross Air be removed. And so the Parts of all *hard Bodies* (and in some measure also of *Liquids*) *cohere* together by *Contact*, that is, by that *Attraction* which always arises from Contact. *See what is said below at* Chap. 22. Artic. 9.

All the Author's Pains therefore about *subtil Matter*, and about the Pores

Matter, which before kept its Parts at a Diftance, and made the Pores fufficiently wide and long, to give free Paffage to the fubtil Matter; and becaufe it cannot thruft the fubtil Matter into the Place which it is difpofed by its Weight to quit, therefore it does not defcend at all: However, not having had any Opportunity to fee how well this Experiment fucceeds, and not venturing to fay that it is falfe, we remain in fufpenfe, and do not determine which Body it is, through the Pores of which the fubtil Matter paffes, to fill the Top of the Tube.

30. But to return to our Difcourfe, and to continue to draw the Confequences which we think deducible from what has been faid above; Let us fuppofe a Tube filled with Quickfilver, and immerfed as ufual in a Veffel, into which Part of the Liquid runs, 'till it is about the Height of Twenty feven Inches and a half, and then it be lifted up a little above the Surface of the Quickfilver, fo that one Drop only of it may run out; then becaufe the Quickfilver, that remains in the Tube, does not weigh fo much as the Air without, it ought to be impelled with Violence to the Top of the Tube, and after that, its own Weight ought to make it defcend on the one hand, as much as the Air makes it afcend on the other; and fo we find it does. *30. What the Confequence will be, if the Tube be lifted up a little, fo that the lower End of it be out of the Quickfilver.*

31. If, after having made the Experiment as ufual, we take the Tube out of the Veffel in which it is immerfed, ftopping the lower Hole with our Finger, but not preffing very hard upon it, then we ought not to feel, nor do we indeed feel the Weight of the Quickfilver: For though it lies upon that part of the Finger, which anfwers to the Hole of the Tube, yet it is not heavy, becaufe it preffes neither more nor lefs, than the external furrounding Air, which is applied to the other Part of the Finger, preffes upon it, and repels it. And if in this Cafe, the Tube be opened at the Top, by fuddenly removing that *31. That we ought not to feel the Weight of the Quickfilver that is in the Tube.*

Pores through which that fictitious Matter fhould pafs, is to no Purpofe. For if there be a Paffage for *that fubtile Matter*, either through the *Quickfilver* or the *Glafs*; yet it would not be able to force the *Quickfilver* up into the Tube, nor to fuftain it there: And if there be no Paffage for it through either of them, then it would not fuffer the Quickfilver to fubfide again, as it does when the Glafs is fhaken. But indeed the Particles of *Quickfilver*, when it is firft cleared of all Air, cohære by mutual Contact, both with one another and with the Glafs; *from a certain Attraction*, which ceafes, as foon as the Tube is fhaken, whereby the Particles are feparated from each other, and from the Glafs. And the fame Experiment has been made in Water well clear'd alfo of Air, by which means its Parts approached nearer to Contact. *See Newt. Opticks, pag.* 337.

which

which it is stopped with, then we should feel the same as if the Finger which is applied to the lower Hole received a hard Blow; because the grosser Air, which descends quick, and with great Force into the Tube, adds on a sudden new Weight to that of the Quicksilver; and this is confirmed by Experience.

32. What ought to be the Consequence of filling up the Tube with any other Liquor.

32. If the Tube be not filled with all Quicksilver, but some other Liquor be put in also, we may determine how far each of them ought to descend, by considering how much that other weighs compared with the Quicksilver. For Instance: Suppose the Tube filled with Quicksilver all but an Inch, and we would fill the rest with Water; because Water weighs but a fourteenth Part so much as Quicksilver, we ought to conclude, that it will make it descend below the ordinary Station, the fourteenth Part of an Inch, and consequently the Water will be Thirteen of the fourteen Parts above that Station.

33. And what, if it be filled with Air.

33. The like Calculation may be made, whatever heavy Liquor be put in instead of Water: However, it is to be observed, that the same Reason will not hold good for *gross Air*. For since we know by Experience, that it has a Power of expanding it self very much, and can easily be mixed with the subtil Matter; we conceive that by mixing it self with that fine Matter with which the Top of the Tube is filled, it presses against the Top of the Tube on the one Part, and upon the Top of the Quicksilver on the other Part, and so by this means forces it much lower than it would force it by its own Weight, which compared with Quicksilver bears no proportion to it.

34. That the Effects of Air are different according to the different Lengths of the Tubes.

34. We foresee also, that an Inch of Air will make the Quicksilver descend so much the lower, by how much less the Tube exceeds Twenty-seven Inches and a half in Length, because the Power of dilating it self, does in a manner resemble a Spring: For as a Spring, the more it is bent, with so much greater Force does it unbend it self; so the Air, the more it is compressed, with so much the greater Force does it dilate it self; and in this, our Reasoning is confirmed by Experience.

35. A very good Experiment of a Carp's-Bladder, to show how much the Air is capable of expanding it self.

35. But to give a plainer Proof [1] how much a little Air, when the Weight of the Column which it sustains is removed, is capable of expanding it self; we need only take a Carp's Bladder, and cutting off the lesser Part at the

1. *How much a little Air*) See the Notes on *Part* III. *chap.* 2. *Art.* 3. *below.*

Neck,

Neck, where it is joined to the Greater, preſs the greater Part ſo cloſe, as to ſqueeze out almoſt all the Air that is contained in it: Then tie it up to keep in that which remains, which is not bigger than a ſmall Lentil: After this, let it be put into the Top of one of the Tubes made large like a Veſſel, and filled as uſual with Quickſilver, and managed in the ſame manner as the forementioned Experiments, and then we ſhall ſee how ſurprizingly the Bladder will ſwell round almoſt all at once, and appear to be blown as big as it was before the Air was let out.

36. Now though there be much more ſubtil Matter in the Bladder thus diſtended, than groſs Air; yet we are not to think, that it is that which preſſes upon the internal Parts of the Bladder, and ſwells it thus; this Effect cannot be produced by it, becauſe it can eaſily return through the Pores by which it entered; it is more likely, [1] that this fine Matter agitates that little groſs Air which remains in the Bladder with great Violence, which Agitation is the immediate Cauſe of the Bladder's ſwelling: And this is ſufficiently evident; for if the Bladder be entirely emptied of the groſs Air, it will not ſwell at all, and if there be a little too much, it will break. *36. What the immediate Cauſe of the Dilatation of the Carp's Bladder is.*

37. In order to make this Experiment well, it ſhould be done with a Tube open at both Ends, and the upper End ſhould be covered with a Hog's-Bladder, moiſtned firſt in Water, that it may ſtretch the better, and this will give us opportunity of obſerving another Circumſtance very curious; and that is, that as ſoon as the Quickſilver begins to deſcend, we ſhall ſee the Hogs-Bladder ſtretched, and forced into the Tube; the reaſon of which is; that then a very heavy Column of Air preſſes upon it, and there is none under it to ſupport it. *37. A remarkable Circumſtance of this Experiment.*

38. If the Bladder be pricked with a Needle, and the Needle be pulled out a little to let ſome of the groſs Air in, and then the Hole be ſtopped; the groſs Air which enters in, will expand itſelf round the Carp's-Bladder, and preſs upon it, and make it appear more or leſs wrinkled, according to the Quantity of Air let in. *38. Another Circumſtance.*

39. This Experiment may ſerve to undeceive thoſe, who upon reading *Ariſtotle* have been of Opinion, *that Air made ten times rarer than it is, neceſſarily changes its Nature, and is converted into Fire*. For the Falſity of this Ima- *39. The Uſefulneſs of this Experiment.*

1. *That this fine Matter*) Not that Matter, for probably there is no ſuch Thing, but only the Elaſticity of the Air it ſelf.

gination is clearly seen, by showing that the Air contained in the Carp's-Bladder is rarifyed above a hundred Times, and yet does not at all alter its Form.

40. That the Height of the Quicksilver is various. 40. When I spoke of the Height which the Quicksilver stands at in the Tube, I limited it to Twenty seven Inches and a half, which is the common Height observed at *Paris*; but to speak exactly, it is sometimes higher, and sometimes lower; because the Air at different times is lighter and heavier.

41. That the greatest Cold ought not to alter the Height of the Quicksilver, and what the Causes are, that ought to alter it. 41. One of the best Observations that I have met with upon this Subject is this: That though we know by Experience, that the Air is condensed by Cold, yet I have never found that the greatest Cold, made any Alteration of the Height of the Quicksilver in the Tube. The Reason of which, in my Opinion, is, that the Cold being very near the same over a great Part of the Superficies of the Earth, the Air does not pass from one Country to another so that the Bulk or Quantity of it is increased; but it being condensed only from the Top to the Bottom, it is the same Quantity of Air, that presses upon any particular Place of the Earth; so that all the Difference that there can arise in the Air, must be imputed to more or less [1] Vapours and Exhalations, which are contained in it at differeut Seasons, and to the Winds which blow sometimes upwards and sometimes downwards.

42. As

1. *Vapours and Exhalations*) It has beeo long observed, that in close and rainy Weather, the Quicksilver does oot rise so high, as when it is dry and clear; which has beeo thought by some to overthrow the whole Theory of the Weight of the Air; and indeed it is very difficult, to explain particularly the Causes of all the various and minute Changes of the Heavens; a great deal is owing to the Winds, which blow sometimes upwards, sometimes dowowards, and sometimes sideways; a great deal to Vapours; a great deal to Steams rising out of the Earth; somethiog must be ascribed to the Alteration of the Heaveos in the neighbouring Countries, and perhaps something to that *Flux* and *Reflux* which the Moon causes in the Air, which is much greater than that io the Sea, *&c.* To account for all which particularly and exactly, would be endless. However, to propose something which may come pretty near the Truth; it is to be observed, that the *Air it self* is heavier than *the Vapours*, and fitted to support them, because its Particles are grosser, and arise from deoser Bodies, than the Particles of Vapours.

In the first Place therefore, this Weight of the Air, *in any particular Country*, may be so chaoged by the *W[illegible]ds*, that the Atmosphere may be [illegible]densed and made heavier, by bring[illegible] greater Quantity of Air, and heap[illegible] together; *viz.* whenever two [illegible] blow at the same time from co[illegible] Parts of the Heavens; or some [illegible] the Air may be carried or blown aw[illegible] them, and thereby an Opportunity [illegible] to the Atmosphere to unfold it self, [illegible] incumbeot Weight being taken o[illegible] *viz.* as often as two Winds blow from the same Country to opposite Parts of the Heavens; or whensoever any one particular Wind is very strong; for it is fouod by Experieoce, that ao artificial strong Wind makes the Air lighter, and the Quicksilver in the Tube to fall very much. *See the*

42. As to any Alteration in the Height of the Quickfilver, which may be thought to arife from the Dilatation of the fubtil Matter in the Top of the Tube, by the Heat of the Summer, or the Contraction of it by the Cold of the Winter, it cannot be at all fenfible: For Experience fhows us, that if this Matter be heated by a Fire, much more than it can be by the Heat of the Sun, it will not

42. That neither the Heat in the Summer, nor the Cold in the Winter, do at all fenfibly dilate or condenfe the fubtle Matter in the Tube.

the Philofophical Tranfactions, Numb. 292.

Secondly, *Cold and nitrous Particles of the Air* it felf, *condenfed by Cold from the North* muft condenfe the Atmofphere where-ever it comes, and make it heavier.

Thirdly, Heavy and dry Exhalations make the Air heavy (in the fame manner as the Specifick Gravity of any *Menftruum* is increafed, by diffolving Salts and Metals) and its *elaftick Force*, as it is called, muft thereby become fo much the ftronger.

Fourthly, When the Air by thefe and fuch like Caufes is become heavy, then is it more able to fupport the Vapours; which when they are entirely mixt with it, and fwim about, and are e[illegible]ry way difperfed in it, make the S[illegible] ferene and clear: But when the [illegible] from the contrary Caufes, is ma[illegible]hter, then is it unable to fupport the Vapours with which it is always filled, and fo being put into fome fort of violent Agitation, they gather themfelves into Clouds and Mifts, and being formed into Drops, fall down.

From thefe Obfervations, it is very evident, that the fame Caufes, which make the Air heavier, and more able to fuftain the Quickfilver in the Tube, make the Heavens alfo clear and dry; and by the fame Cauf[illegible] which the Air is made ligh[illegible] and lefs able to fuftain the Q[illegible]kfilver, are Showers and R[illegible] produced alfo.

Hence it foll[illegible] Firft, That when the Air is [illegible]eft, and the Quickfilver fal[illegible]weft in the Tube, then the C[illegible] move very low and quick; [illegible]d that clear Air, which after Rain, appears between the thick Clouds, being difcharged of its Vapours, feems moft tranfparent and bright, and gives the beft and eafieft profpect of Things at a diftance.

Secondly, When the Air is more heavy, and the Quickfilver is raifed higher in the Tube, then the Heavens are fair, but a little thicker, and not quite fo blue, by reafon of the Vapours which are every way equally difperfed about; and as has been by many obferved, it does not afford fo good a Profpect of Things at a diftance; and if there do appear any Clouds, they are very high and move very flow; and when the Air is heavieft of all, the Earth is fometimes covered with very thick Clouds, which feem to confift of heavier fort of Exhalations, which the Air at that time is capable of fuftaining, but which cannot fwim in lighter Air.

Thirdly, Hence it is, that in our own Country, when the Cold is greateft, and the North and North Eaft Winds blow, the Quickfilver in the Tube is higheft; becaufe at that time two Winds blow together upon our Country from oppofite Parts of the Heavens; for in the Atlantick Ocean, at the fame *Latitude* with us, the Wind blows almoft always from the Weft. To which we may add, that the Air which is brought hither by the North Wind, comes condenfed by the Cold.

Fourthly, In the moft Northern Countries, there is greater Variation of the Height of the Quickfilver in the Tube, than in thofe Countries which are more South, becaufe in thofe Countries, the Winds are ftronger and more variable, and oppofed by each other in a lefs Tract of Land; whence the *Air* is fometimes more heaped up and condenfed, and fometimes carried away and lightned.

Laftly, Between the Tropicks, there is the leaft Variation of all, in the Height of the quickfilver in the Tube, becaufe there the Wind is for the moft part very gentle, and blows the fame way.

See *the Philofophical Tranfactions, Number* 181.

make the Quickfilver defcend at all; and if the Heat of Summer can do nothing towards fenfibly dilating it, the Cold of the Winter can much lefs do any Thing towards the condenfing it.

43. How much the greateft Difference in the Height of the Quickfilver is.

43. But whatever be the Caufe of the Quickfilver's rifing and falling in a Tube, where the Experiment is continual; the greateft Height that I have obferved for fifteen Years, in a Tube which I prepared for that Purpofe, was Twenty eight Inches, and a third Part of an Inch; and the loweft was Twenty fix Inches and feven twelfth Parts of an Inch; fo that the greateft Difference in the Height of the Quickfilver, was an Inch and three quarters.

44. That the Height of the Quickfilver ought to be different in Places of a different Height.

44. Though all thefe Experiments are fufficient to convince us, that it is by the Weight of the Air, that the Water or Quickfilver is fupported or made to rife in the Tube; yet it is eafy to conceive how there may be an Alteration made in the Height of the Quickfilver, and yet no Change made in the Air it felf: In order to this, we need only make the Experiment in two different Places, the one the higheft, and the other the loweft that we can come at: For there being a lefs Quantity of heavy Air in the higheft Place, the Quickfilver cannot be fupported by it to fo great a Height as in the loweft.

45. The firft Experiment.

45. Now in order to try if Experience would agree with our Reafoning, I filled a Tube three Foot and a half long, with Quickfilver, and immerfed it into a deep and ftrait Veffel, into which it emptied it felf as ufual; after which I fixed them both in a Wooden Frame, made for that Purpofe: And now the Inftrument being fuch as could conveniently be carried from one Place to another, without any Danger of fpilling: I carried it to the Surface of the River *Seine*, which happened then to be frozen, and obferved exactly the Height of the Mercury: After which, I went up one of the Towers of the Church of the *Virgin Mary* at *Paris*, which is about Two hundred and fixteen Feet higher than the Place where the first Experiment was made; and here I found the Quickfilver was not fo high in the Tube as before, by near three Lines, that is, near a quarter of an Inch.

46. Another more fenfible Experiment.

46. The fame Experiment was tried in *Auvergne*, in one of the loweft Places of the Town of *Clermont*, and upon the Top of a neighbouring Mountain, called *Puy de Dome*, which is about Three thoufand Foot higher than the Vally, and the Difference in the Height of the Quickfilver was found to be above three Inches.

47. As

47. As this Experiment is more ſenſible than mine, if it was made, as there is Reaſon to think it was, with all the Exactneſs one could wiſh; it furniſhes us with an eaſy Method of finding the Height of the whole Air, ſuppoſing it to be every where of the ſame Denſity as it is near the Earth: For ſince upon taking away Three thouſand Feet of Air, the Quickſilver ſinks three Inches, this is a Proof, that a Column of Quickſilver of three Inches high, weighs equal to Three thouſand Feet of Air, and conſequently the Height of the whole Air, which counterpoiſes Twenty ſeven Inches and a half of Quickſilver, is Twenty ſeven thouſand and five hundred Feet high. *47. A Method of finding the Height of the Air.*

48. As therefore we conclude, that when there is leſs Height of the groſſer Air to preſs upon the Quickſilver in the Veſſel; there ought alſo to be leſs Height of that in the Tube; for the ſame Reaſon, if we ſuppoſe that there were no groſs Air at all to preſs it upwards, we ought to conclude that all the Quickſilver would fall down, ſo that *That* in the Tube would be level with *that* in the Veſſel. *48. That all the Quickſilver would fall out of the Tube, if there were no groſs Air to preſs upon the Veſſel.*

49. Some have imagined it impoſſible to make any Obſervation by which it ſhould appear, that Reaſon and Experience agree in this Particular; becauſe there is no Mountain high enough to carry us up to the upper Surface of the Air; and becauſe, if there were, the Air would be ſo thin, that we could not breathe in it. But I thought of a Means to remove theſe two Difficulties, and by which the Thing might eaſily be effected; and that was, to prepare ſome ſmall Room, with tranſparent Walls, which one might ſtand without and look upon, without any Danger from what might happen within. I cauſed therefore a Glaſs Inſtrument to be made, according to the following Repreſentation. BC is a Tube, upwards of Twenty ſeven Inches and a half long, and is open at C: AB is a large Cavity, which has a Communication with BC by the Part BL, which is cloſed, and has no Aperture at A: DE is a ſmall Glaſs Tube ſtopped up at the End D, and ſticks out of the Cavity AB by the Length FE, and is open at E: Beſides there is a ſmall Hole F in this little Tube, where it is cemented on the outſide to the Glaſs AB in ſuch a manner, that the Cavity of the little Tube has a Communication, with the large Cavity AB by this little Hole F: Laſtly, by means of the Neck BG, the external Air has a Communication with that in the whole Tube ABC. *49. A Deſcription of an Inſtrument to make this Experiment.* *Tab. I. Fig. 7.*

50. I

50. How the foregoing Instrument is to be used. 50. I firft ftop the Hole G with a Hog's-Bladder, and turning the whole Inftrument, fo that the End C may be uppermoft, then I pour in the Quickfilver at the Hole E, which at firft falls only into the little Tube DFE, but when it is full up to F, then continuing ftill to pour in, it runs through the Hole there, and fills the Cavity AB which furrounds this Tube, which I fill up as high as B; then I fill the reft of the large Cavity, pouring the Quickfilver in at C, 'till it rifes as far as the Hole E, which I ftop then with a Hog's-Bladder; after this, I continue to pour the Quickfilver in at the Hole C, 'till the Tube BC is quite full: Having done this, I ftop the Hole C with my Finger, and invert the whole Inftrument which is full of Quickfilver as ufual, and immerfe it in a Veffel of the fame; Then the Cavity AF empties itfelf as far as IL, and at the fame Time, the little Tube DFE empties itfelf to the fame Height, and the Tube C empties it felf to H which is Twenty feven Inches and a half above the Quickfilver in the Veffel: And thus we fee that Reafon and Experience agree: for as there is no grofs Air to prefs upon the Surface IL of the Quickfilver which remains in the Bafon IFL, fo there is nothing to force it to rife in the little Tube DFE.

51. Surprizing Effects from the Entrance of the Air into the Inftrument. 51. Now if the Hog's-Bladder which ftops the Hole at G, be pricked with a Needle, it is evident, that the groffer Air which enters into the Cavity ABG ought to produce Two very different, and therefore very remarkable Effects: The firft is, That preffing upon the Quickfilver which is directly under G, it will caufe it to defcend; and alfo preffing upon the Surface IL of the Quickfilver which remains in the Bafon IFL, it will make Part of it to afcend in the little Tube DFE, and fill it quite full, provided it does not exceed Twenty feven Inches and a half in Length. The Experiment will be more pleafant, if after the Hog's-Bladder, with which the Hole G is ftopped, be pricked, the Needle be pulled back feveral times a very little, to let a little Air in at a time through the Hole, and then thruft forward to ftop it again: for then you will have the Pleafure to fee the Quickfilver in the little Tube DFE afcend by little and little at the feveral times, and that in the Tube BC defcend in the fame manner. Then if the Needle be pulled out all at once, you

you will see at the same time it will rise as much on the one Hand, as it falls on the other. [1]

52. If the Liquor with which the Bason belonging to the Tube is filled, falls all down, because there is no Air to support it, as we see in the foregoing Experiment, where the little Tube DFE, is entirely emptied of the Quicksilver; the Reason holds stronger for its not rising, if there be no Air to thrust it up; wherefore there is no need of making any Experiment, to be assured, that the Water ought not to rise in a Syringe, when the Sucker is drawn, if the Vessel in which the End of the Syringe is immersed, be so stopped, that the external Air cannot enter into it. But if any one be still so obstinate, as not to be content without referring it to Experience, he need only put the End of the Syringe into the Mouth of a Glass Bottle, which is round and strong, and full of Water; but not begin to draw the Sucker, 'till the Mouth of the Bottle be well stopped with Wax, or some such Thing, to prevent the external Air entring; and then he will see that the Water will not rise at all in the Syringe. *52. That the Water cannot be drawn into a Syringe where there is no Air to support it.*

53. That we may go on to explain the most considerable *Phænomena* of Hydraulick Instruments; I come now to give an Account of the Syphon. Let ABCD then be such a Syphon, the shorter Arm of which CD is put into a Vessel of Water; Then, as has been often said, the Air which presses upon the Water which is in the Vessel, ought not to make it rise up in the Syphon, because the Air which is in the Syphon hinders it. *53. Why the Weight of the Air does not at all raise the Water in a Syphon.* Tab. II. Fig. 1.

54. But if the Water in the Vessel be made to rise up into the Syphon, either by sucking it at the End A, or any other way, so that it be filled quite full of Water, and then we take our Mouth away from the Hole A, the Water will not cease to run, but continue running, so long as the shorter Arm CD remains in the Water in the Vessel: The Reason of which is this. So long as the shorter Arm CD is immersed in the Water, the Force of the Air indeed which presses upon the Water in the Vessel, and which endeavours to make it rise in this Arm, is not sensibly greater or less, than the Force of the Air which endeavours to repell it, when it offers to run out at the Hole in the other Arm: But because the Force of *54. What is the Cause of the Waters rising in the Syphon.*

1. You may find the Description of an Instrument not much unlike this in the *Experiments of the Academy del Cimento*. But the Air Pump of the famous Mr. *Boyle* exceeds them all, and is so well known, that I need not describe it.

each

each of these two Arms is diminished, in proportion to the Weight of the Water which each of them impels; and the Weight of the Water in the longer Arm being heavier, than that in the shorter Arm; it follows, that there remains more Force in the Air which acts upon the Water in the Vessel, to make it rise up in the shorter Arm, than there does in the other to repel; so that it is indeed made to rise, and forced to run out through the longer Arm, notwithstanding the Resistance of the Air which opposes it.

55. How high the Arms of the Syphon must be for the Water to ascend.

55. I here suppose, that the Arms of the Syphon do not exceed that Height of the Liquor which the Air would sustain in a perpendicular Tube; for if they be longer, the Liquor with which the Syphon is filled, will divide at the Top, and descend in each of the Arms; which is confirmed by Experience.

56. How the Air is drawn into a pair of Bellows.

56. After so many different Explications as have been already given, I don't think it necessary to inlarge much upon explaining how the Air enters, and is received into a Pair of Bellows; for it is easy to apprehend, that when the Sides are separated from each other, they thrust forward the Air, which not being able to move freely every way [1] because the World is full; or at least not being able to enter in at the Nose with Ease, and quick enough to fill readily that Space which is left by the Sides of the Bellows when they are opened, it is turned back, and enters with Ease and Swiftness through the Holes of the Bellows.

57. How we draw in the Air by Respiration.

57. It is proper here to observe, that we receive in the Air by Respiration, much after the same manner: For it is certain, That the Muscle of the Thorax and Abdomen, serve to distend, and swell the Body, by which Means the Air being thrust back, gets into the Hollow of the Lungs through the Mouth and Nostrils.

58. Whence it is that we find no Difficulty in breathing.

58. The only Difficulty here is, that since we sustain a great many Columns of Air, which are all heavy, and which press upon the external Parts of our Body, and thrust it inwards; it should seem that we ought to feel some Difficulty in breathing, in order to overcome this Resistance: But the Answer is easy; For if there is some

1. *Because the World is full*) Whether the World be full or not, it is the same Thing; for it cannot be, but that the Air by its own Weight (*and Spring*) must rush into the empty Bellows when they are open. Which I remark here to show, that whatever becomes of the Fulness of the World, the Explication of these and such like Motions, is the same.

to

to thruſt it inwards, there are alſo a ſufficient Quantity of others, which enter into the Cavity of the Breaſt to preſs it outwards; ſo that there is an *æquilibrium* between theſe Forces or Powers: and this is the Reaſon why we ought not to find any Difficulty in Breathing, or if we do, it is owing to ſome other Cauſe.

59. The ſucking in of Air through a Quill is done in the ſame manner as Reſpiration; for it is the ſame as if our Mouth were as long as the Quill. *59. How it is that we ſuck in Air.*

60. If we try to ſuck a heavy Liquor through a Quill dipped into it, we ought to find ſo much the greater Difficulty as the Quantity of Liquor we make to riſe is greater; becauſe this Liquor preſſing by its Weight upon the external Air which endeavours to raiſe it in the Quill, [1] hinders it from impelling and aſſiſting the Air which is in the Lungs, ſo much as it uſually does; by which means the Air in the Lungs is weakned, and has juſt ſo much leſs Force to thruſt the Parts of the Body outwards, than the Air which is applied to the external Surface of the Body has to thruſt them inwards, as the Liquor which is cauſed to riſe in the Quill is heavier. *60. Why it is more difficult to ſuck a heavy Liquor.*

61. I ſhall finiſh what I have to ſay concerning this Sort of Motions, with explaining that Swelling which Surgeons make in the Fleſh, by the Application of Cupping-Glaſſes; the common Method of which, and that to which all others may be reduced is this; They take a ſmall round Card, upon which they fix four ſhort pieces of Wax-Candle, which they light, and ſet like a Candleſtick upon the Part of the Body which they intend to cup: Then they cover all the Candles with the Cupping-Glaſs, but do not put it cloſe to the Fleſh, 'till the Air that is within it, is ſufficiently heated; then as ſoon as it is *61. Concerning the Uſe of Cupping-Glaſſes.*

1. *Hinders it from impelling*) If the eotire Weight of the Liquor be coofidered; we muſt ſay, that the Difficulty of Sucking, is therefore greater or leſs, becauſe in proportion to the greater or leſs *Height* or *Thickneſs* of the Column of Liquor, the Breaſt is more or leſs diſtended by the Power of the Muſcles; ſo that the Reſiſtance of the internal Air (which it endeavours to hinder the Liquor from riſing) *muſt be* ſo much more or leſs weakned by Rarefaction, according to the Power of the external Air, to raiſe up the heavy Liquor to the Mouth. But becauſe the Columns of Liquor are raiſed by the external Air with leſs or greater Difficulty, according as they are leſs or greater in *Height* and not in *Thickneſs*; therefore if we ſuppoſe two ſuch Columns, one of which is twice as high as the other, aod this other twice as thick at that; though it be plaio, that in both Caſes, there is the ſame Quantity of Air to be ſucked out of the Quill, and the ſame Quantity of Liquor to be ſucked through it; yet it is evident, that a greater Diſtention of the Breaſt, and a greater Force of the Muſcles is required, that is, it is more difficult to ſuck or raiſe up the Firſt than the Second.

put

put close, the Candles go out, and we see the Flesh swell, and rise up.

62. Why the Flesh swells. 62. In order to understand the Reason of this Experiment, it is to be observed; that during that short time that the Candles continue light, the Air which is in the Cupping-Glass, [1] though very much agitated and dilated by the Flame, does however press upon the Flesh, as much as it did before; because the Cupping-Glass being not yet put quite close, does not take off any of the Weight, which it had before it was dilated; but it is otherwise after the Candles are extinguished by the immediate Application of the Cupping-Glass to the Body: For then the Air which is contained in it, is no longer pressed upon by the Air without; and as it grows cooler, it has not Force sufficient to take up such a Compass, as when it was agitated by the Heat: Wherefore since all the other Parts of the Body are pressed upon by the external Air, which also presses the Cupping-Glass to the Body, the one must of necessity enter into the other; that is, the Flesh must be thrust into the Cupping-Glass, and the Air within it condensed.

1. *Though very much agitated and dilated by the Flame, does however press upon the Flesh as much as it did before, because the Cupping-Glass being not yet put quite close, does not take off any of the VVeight, which it had before it was dilated.)* This Explication had been somewhat more plain, if the Author said——*though dilated by the Flame, yet since it is very much agitated, it does however.* Nor was *there any need of having recourse to the Weight of the external Air here.*

CHAP. XIII.

Of the Determination of Motion.

1. What is meant by the Determination of Motion. WHEN a Body moves any particular way, the Disposition that it has to move that way, rather than any other, is what we call its *Determination.*

2. That such Determination is something distinct from Motion. 2. *Determination* is a Mode which is distinguished from *Motion,* and which may remain the same, how much soever the Motion be increased or diminished: Thus a Stone that falls freely in the Air, has a certain Quantity of Motion, and at the same time has also a certain Quantity of *Determination* of Motion downwards; and

The first Proof.

and if it had been thrown oblique from the same Place, so as to have come to the Ground in the same time, it would have had the same Quantity of *Determination*, but a greater of Motion.

3. Another Proof that *Determination* differs from *Motion*, is, that it depends upon a different Cause from that of Motion; thus in a Ball struck by a Racket, the Motion is owing to the Force with which the Racket is moved, but the Determination towards any Part is owing to the Situation of the Racket. *3. Another Proof.*

4. Since every Thing endeavours as much as it can to continue in the State in which it once is, it is evident, that a Body which has once begun to move with a certain *Determination*, ought always to keep the same; that is, it ought always to move in a streight Line; for this is the only *Determination* that is [1] natural to a Body in Motion: Wherefore when it was said above, that when any Body was moved in a streight Line, other Bodies must necessarily be moved with a circular Motion, we are not to think, that those which thus turn out of a streight Line, tend to do so of themselves, but that they are forced to do so, by meeting with, and being impelled by other Bodies. *4. That a Body does not tend of it self to go out of the way, but only to move on in a streight Line.*

5. Therefore when we see a Body move in the Sides of a Square, we conclude, that in the Places where it changes its *Determination*, it is forced to turn out of the way, by meeting other Bodies, the Resistance of which, it could not overcome. So likewise if a Body moves through the Sides of an Octagon, we can't but say, that *5. That every Body which moves in a Circle, is forced to do so.*

1. *Natural to a Body in Motion*) Mr. *Perrault* in his *Tentam. Phys. Tom.* 1. *p.* 80, 88. contends, that Motion in a Circle is as natural as in a streight Line; for terrestrial Bodies turned round, endeavour to go off from the Center of their Motion, because they are heavy; but if a Body that had no Weight at all were turned round, it would move about its Center freely without any Impulse, and would not endeavour to go off from it. Thus if a Ball of Wax be so made hollow, as to equal in Weight an equal Bulk of Water, it will so comply with the Motion of the Water turned round in a Vessel full of Water, that it will always describe the same Circle, and never attempt to go off from the Center of its Motion. But (besides that there is no such Thing as a Body void of all heaviness) this Assertion is contrary to all Reason, and this very Experiment proves nothing less, than what this eminent Person imagined: For what can be more evident, than that this Ball endeavours to go off from the Center of its Motion, but cannot get off, because all the Parts of the Water endeavour at the same time to go off from the same Center, and with the same Force, because equally solid; and therefore since the Sides of the Vessel hinder them from going all off together, there is no reason why the Ball of Wax should recede from the Center, and impel the Parts of the Water to the Center, any more than there is for the Parts of the Water to recede from the same Center, and drive the Ball thither,

it

it is eight times forced to turn out of the way; and ſince a Circle is equal to a Figure of an infinite Number of Sides; it follows, that a Body which moves in a Circle is forced to turn out of the way every Moment, either by the continual Reſiſtance of Bodies which it every where meets with, or becauſe it is retained by ſomething which obliges it to keep always at the ſame Diſtance, and to run through the Circle deſcribed; otherwiſe it is certain it would not deſcribe a Curve Line at all.

6. If that Force ceaſes, then it ought to move in the Tangent of that Circle which it deſcribed before. Tab. II. Fig. 2.

6. For Example; if the Body A deſcribes by its Motion part of the Circle BCD, it muſt be continually turned out of its Courſe from one of the forementioned Cauſes: If, when it comes to the Point D, it ſhould be no longer forced; either becauſe the Bodies which it meets with, ſhould make no further Reſiſtance, or the Thread which connected it with the Center, and hindred it from flying off, ſhould break; it would not continue to deſcribe the Arch DEB, but it would deſcribe a ſtreight Line, which would run the moſt directly that is poſſible from the Arch CD, that is, it would deſcribe the Line DF, which is the Tangent of this Circle, and makes the leaſt Angle that can be with the Circumference, and which, as you ſee, grows more and more diſtant from the Center: This is confirmed by an infinite Number of Experiments.

7. Bodies which move in a Circle, endeavour to go off from the Center of the Circle which they deſcribe, and make other Bodies approach to it.

7. And ſince a Body in Motion, has always a Tendency to deſcribe that Line, which it would deſcribe if it were at liberty; and what was ſaid of the Body A, is to be underſtood in general of all other Bodies; we muſt conclude, that Bodies which move in a Circle, have a perpetual Tendency to recede from the Center of their Motion; and this they ought to do with a Force ſo much the greater, as their Motion is quick. Wherefore, if the greater part of the Space contained in the Circumference BCDE be full of Bodies which move round the Center G, *they* will puſh all the other Bodies with which they are encompaſſed, and drive them as far from the Center as they can: But if theſe Latter can find no Place to retire to, they will be forced, in order to give Place to the other, to go nearer the Center; in the ſame manner as when we dip our Hand into a Pail of Water, the Water is forced to give way to our Hand, and to remove from the Bottom which it has a Tendency to by its own Weight.

8. That a Body in Motion meeting with another Body which it cannot move, ought to be reflected.

8. It is evident, that a Body loſes ſo much of its own Motion as it communicates to other Bodies: Now if it communicates no Motion at all to others, (we do not here

here consider what may be occasioned by its Softness, Weight or Figure) we have no Reason to think that it should at all abate of its Velocity. Wherefore if a Body in Motion strikes upon another, which it cannot move at all, we ought to conclude, that it will continue to move on with the same Celerity as it did before; but because the Body which it cannot move, hinders its *Determination*, it must necessarily alter this *Determination*, that is, it will be *reflected*.

9. This *Second* Determination, may indeed be contrary to the *First*: but because the Notion we have of *reflected Motion* is not different from the Notion we have of *direct Motion*, we ought not to think that these Motions are contrary to each other, but that [1] the one is only a Continuation of the other, and consequently, that there is not any Moment of Rest in the point of Reflexion, as some Philosophers have imagined. *9. That there is not a Moment of Rest in the Point of Reflexion.*

10. Besides, if a Body which was in Motion, comes to be but one Moment at Rest, it will have wholly changed its manner of existing into the contrary, in which there will be as much Reason for its continuing, as if it had been at Rest a whole Age; in the same manner, as if a Body which was once square, was made round but one Moment, it will have as much Reason as ever it had, to continue in this Figure. *10. That Reflexion would be impossible, if there was a Moment of Rest.*

11. When a Body falls perpendicular upon another, which is hard and immoveable, it is evident, that the Reflexion ought to be made in the same Line, in which the Body moved before, there being no Reason why it should incline one way rather than another: Wherefore there is no Difficulty in this Matter, except when the Line in which the Body begins to move makes oblique Angles with the Superficies of the Body against which it strikes. But the Judgement we are to make of this, depends upon what we are going to say concerning the Composition of Motion, and of its Determination. *11. That a Body which falls perpendicularly upon another, ought to be reflected perpendicularly.*

1. *The one is only a Continuation of the other*) But it is not so. *For Bodies which are either absolutely hard, or so soft as to be void of Elasticity, will not rebound from each other, Impenetrability only makes them stop. Newt. Optic. pag.* 373. See above, Chap. x. Artic. 13.

Further, there may be a Moment of Rest, in the Point of Reflexion: because the reflected Motion, is not a Continuation of the Direct; but a new Motion impressed by a new Force, *viz.* the Force of *Elasticity*.

As to what our Author says; that if the Body rested but one Moment, it ought as much to continue in that new State of Rest, as if it had rested a whole Age; it is indeed true, with regard to the former Motion; but since *Elasticity* is the Cause of a new Motion, the Reason is very different.

CHAP. XIV.

Of the Composition of Motion, and of its Determination.

1. *What is meant by compound Motion.* ALL Motion that depends upon two or more Causes, we call *Compound* Motion: Thus, if one Force acting upon the Body A, would cause it to move along the Line AB, and at the same time another Force acting upon the same Body A, would cause it to move along the Line AC, the Motion which will arise from the Action of these two Forces, or from these two Causes, will be a *compound* Motion.

Tab. II. Fig. 3.

2. *Two other Motions being given to find the compound Motion.* 2. In order to find out what Line the Motion, which depends thus upon two Causes, ought to be made in; let the two Lines be drawn, which the Body would move in, if each of these Causes produced their Effect separately. For Example, if the first Cause would in a given Time, make the Body A move from its Place, as far as B; and if the Second Cause would in the same Time, make it move to C; let the Lines AB, AC, be drawn; then having divided the Time in which this Motion was made, into as many equal Parts as you will, divide the Line AB into as many, by the Points E, F, G, and the Line AC into as many also, by the Points H, I, L; so that, if the first Cause acted alone, the Body A would come to the Point E, in the first Part of the Time; to the Point F, in the second Part; to the Point G in the third Part; and to the Point B in the Fourth; and if the second Cause, produced its Effect separately, the Body A would come to the Point H in the first Part of Time; to the Point I in the Second; to the Point L in the Third; and to the Point C in the Fourth: After this, draw the right Lines EM, FN, GO, BD, parallel to the Line AC; and the Lines HP, IQ, LR, CD, parallel to the Line AB: This being done, the Points S, T, U, D, where these Lines intersect each other, will determine the Line in which the Compound Motion is made.

Tab. II. Fig. 3.

3. *A Demonstration of compound Motion.* 3. For it is certain, that the first Cause is answered, by allowing the Body to move to the Line EM in the first Part of Time, and the Second is answered, if we allow it to be found in the Line HP in the same time; wherefore both these Causes are answered at once, if the Body comes

comes to both the Lines EM, HP, at the ſame Time; which it cannot do, but at the common Point S. Again, it is evident, that the firſt Cauſe is anſwered, if we allow the Body to come to the Line FN in the ſecond Part of Time; and the ſecond Cauſe is anſwered, if it be allowed to come to the Line IQ in the ſame Time; and conſequently it is certain, that, in order to anſwer both theſe Cauſes together, it muſt be found in theſe two Lines at the ſame time; *viz.* in the Point T where they interſect each other. So alſo we may prove, that the Body ought to be found in the Point V, where the Lines, GO, LR, interſect each other, to anſwer the ſame two Cauſes; and at laſt in the Point D, where the Lines BD and CD interſect one another [1].

4. In what Lines compound Motion may be made.

4. Where [2] the ſimple Motions are equal, as in the firſt Figure, the compound Motion is in a *ſtreight Line*: But where the ſimple Motions are unequal, as in the Second Figure, the Motion will be made [3] in a *Line* differently *curved*, according to the different Inequalities of the ſimple Motions.

5. How to determine a Motion compounded of more than two ſimple ones.

5. If more than two Cauſes concur to produce a compound Motion, it may be determined in this manner: Firſt draw the Line in which the Body ought to be moved, ſo as to anſwer two Cauſes; then, taking the Motion in this Line as if it aroſe from one Cauſe only, draw the Line which it ought to deſcribe, ſo as to anſwer this

1. Such a kind of Motion as this, is that of an Arrow, in the famous Experiment of a Ship under full Sail; where an Arrow being ſhot perpendicular, falls down again upon the ſame Place on the Deck, whence it was ſhot: For the Arrow has a double Motion impreſſed upon it at the ſame time; one by the Bow and Hand which ſhoots it, and the other by the Ship moving along. Something like this was obſerv'd at *Florence*, where a Leaden Ball ſhot perpendicularly out of a Musket fixed in a Wooden Carriage made to move very ſwiftly, fell about ſeven Foot on this ſide the Mouth of the Musket, which moved Sixty four Paces. See *Exper. Acad. del Cimento. p.* 145. Perhaps the Musket, was not erected exactly perpendicular, or was moved ſomewhat ſwifter after the Ball was ſhot out, than when it was ſhot; or if neither of theſe happened, yet the Reſiſtance of the Air, which could not but retard the Motion of the Ball, might perhaps be the ſole Cauſe why the Ball fell ſo much on this ſide the Musket.

2. *The ſimple Motions are equal*) It is to be obſerved, that thoſe ſimple Motions which are here compared with each other, and are called equal or unequal, are not thoſe of different Determinations (ſuch as AB, AC,) but the Parts of the Motion of one and the ſame Determination (*viz.* AE, EF, *&c.* AH, HI, *&c.*) compared together. Fig. 3.

3. *In a Line differently curved*) When one or both the ſimple Motions is altered gradually and every Moment; the Line which is deſcribed, may be conceived to be bent into an infinite Number of ſmall Lines which end in a Curve. Such is the Motion of *projected Bodies*. See *the Notes on Part* II. *ch.* 28. *Artic.* 16.

Cauſe,

Caufe, and a Third, and fo on, if there be a Fourth or fifth Caufe, producing its particular Effect.

6. That the Motion of a Ball out of a Cannon, is a compound Motion.

6. It is eafy to fee, that the Ball of a Cannon which feems to be driven by the Fire level with the Horizon, does notwithftanding move in a Curve like that defcribed in the fecond Figure; for there are two Caufes which concur towards its Motion, the firft of which, *viz.* that which caufes the Ball to move upon the Level, ought continually to diminifh, becaufe it communicates, by little and little, its Motion to the Air which it difplaces: and the fecond ought to increafe, becaufe we find by Experience, that the Fall of a heavy Body is flower at the Beginning than afterwards.

7 That the levelling it at the Mark, fhows that the Ball defcends.

7. The Exactnefs of the Cannoneer in levelling the Cannon to the Mark which he looks at, ought not to make us alter our Opinion, and to think immediately that the Ball is carried in a ftreight Line: For if we obferve, that the Cannon is not every where of an equal Thicknefs, and that the Line AB by which the Mark is aimed at; is at firft above, but goes afterwards below the Line of Direction CD; we fhall conclude, that if the Ball hits the Mark, it has doubtlefs fallen a little, or elfe it would have gone a little above it.

Tab. II. Fig. 4.

8. What is meant by compound Determination.

8. As there are *Compound Motions*, fo alfo are there *compound Determinations*, and, it may be, when the Motions are the moft fimple that can be: Thus we fay, a *Determination* is compounded of two others, when a Body moving in a fimple Line to a certain Place, is at the fame time carried two different Ways; as if the Body A be moved with a fimple Motion from A to B; becaufe at the fame time, it continually approaches the Lines BC, BD, we fay, that the *Determination*, by which it is carried from A to B, is compounded of two others, one of which would make it go towards D, and the other at the fame time carry it from A to C; and thefe Diftances are the Meafure of its Progrefs towards thefe different Parts.

Tab. II. Fig. 5.

9. That one and the fame Determination may be compounded of many different ones.

9. For the fame Reafon that we confider any one *Determination* as compounded of two fimple *Determinations*, we may as well confider it as compounded of innumerable others. Thus the *Determination* from A to B may be confidered as compounded of the *Determinations* from A to E, and from A to F; becaufe when the Body A moves from A to B, it continually approaches BE and BF

alfo,

alſo, from which it was diſtant by the Length AE and AF 1.

1. From this Principle, the Method of explaining the Forces of the *Mechanick Powers* (as they are called,) may excellently well be deduced.

For ſince a Body with two united Forces, always deſcribes the Diagonal of a Parallelogram, in the ſame Time, as it would do the Sides, if the Forces were ſeparate; it is evident, that any Force whatſoever, acting in a given Direction, may be looked upon as the Effect of two other Forces acting in Directions, which at the ſame Point, ſhall on each ſide, be any way inclined to the given Direction, provided they make an Angle leſs than two right ones: And this is abundantly confirmed in Mechanicks; for by ſuch a Reſolution of a given Force into two others, the known Properties of the Mechanick Powers, ſuch as *the Ballance, the inclined Plain*, &c. may eaſily be deduced.

Of the *Ba[llan]ce* or *Leaver*. Prop. I.

If two Forc[es], which act upon the Arms of a Ballance in given Directions that are in [th]e ſame Plain with thoſe Arms, ballance one another; theſe Forces are to each other reciprocally, as Perpendiculars let fall from the Center of the Ballance, to their Directions.

DEM.--(*See Newt. Princ. pag.* 14.

Let C be the Center of the Ballance. Cp, CP the Arms, Ep, PA the Directions of the Forces acting upon [the] Arms Cp, CP. Let CE be drawn perpendicular to [E]p, and CD to PA, meeting the[m] in E and D. On the Center [C, a]nd with the Radius CE, *viz.* [th]e longeſt of the Perpendicul[ars], let a Circle be deſcribed [whi]ch ſhall interſect the Dire[ctio]n of the Force P in A, and let [the] Line CA be drawn: to which let [A]G be drawn perpendicular, and GF parallel, meeting DPA in F.

Tab. xx. Fig. 1.

It is evident, that the Arms of the Ballance CP, Cp, may be looked upon as Lines that will not bend, lying in the Plain moveable about the Center C; and the ſame may be underſtood of any other Lines drawn through the Center C, and lying in the ſame Plain. Now ſince it is manifeſt, that there is no difference in what Points of the Lines, in which the Forces P and p act, thoſe Forces are placed; ſince whereſoever they are in thoſe Lines, they will have exactly the ſame Power to turn the Plain CDApE about its Center: the Forces P and p may be ſuppoſed to be in the Points A and E. Then the Force P, ſuppoſed to be in A, may be reſolved (as was before obſerved) into two other Forces: One of which may act according to the Line CA produced, and the other, according to the Line AG; and which may be to each other as FG to GA; but each of them ſingly to P, as FG and AG ſingly to AF; as will be evident, if the Triangle AGF be compleated in the Parallelogram AGFg. It is alſo manifeſt, that the Force, which is as FG, and which acts according to the Line CA paſſing through the Center of the Plain, does nothing at all towards turning that Plane about the Center C: but the Force which is as AG, and which draws the Line CA perpendicularly; ſince, by the Hypotheſis, it ballances the Force p, which draws the Line CE, equal to CA (*by Conſtruction*) perpendicularly alſo, it muſt neceſſarily be equal to it. Wherefore p will be to P as AG to AF; or as DC (*by reaſon of the ſimilar Triangles* FGA, ACD) to CA or CE: That is, the Forces p and P are to one another reciprocally as Perpendiculars let fall from the Center to the Lines in which they act.

Coroll.

If the Arms lie in a ſtreight Line and the Determinations of the Forces be parallel, it is evident, that the Forces are reciprocally as the Length of the Arms.

2. Hence alſo, in the Angular Ballance PCp, which turns about the immoveable Center C; the Situation which it will be in, when any two given Bodies are fixed to the Ends P and p, may be determined. For if the Line Pp which joins the Ends of the Ballance, be divided in reciprocal Proportion to the Weights, and the Point of Diviſion

Tab. XX. Fig. 2.

 T be

10. *That it is not necessary to consider all the Determinations of which One may be composed.*

10. But it is not necessary to consider all the simple *Determinations*, of which One may be composed: It is sufficient

T be made in the Line CT drawn through the Center, parallel to the Direction of the Weights; I say it is done: For PD and *p*E being drawn parallel, and DCE perpendicular to CT; it is evident that DCE is divided in C, in the same Proportion that PT*p* is in T, and that the Weights may be supposed to be placed in the Points D and E. Wherefore this will be the Situation of the Points P and *p*, that is, of the Ballance it self when the Weights are in *æquilibrio*.

3. In the Ballance or Leaver, it is evident, that two Forces, such as P and *p* which when the Ballance librates to and fro, are reciprocally as the Velocities of the Points D and E, reckoned according to the Directions of those Forces, will ballance each other. Tab. XX. Fig. 1.

Of the *Inclined Plain*. Prop. II.

If a Force, with a given Direction, supports a Weight upon an inclined Plain; that Force is to the Weight, as the Sine of the Inclination of the Plain, to the Sine of the Angle which is made by the Line in which the Force acts, and the Line perpendicular to the Plain.

D E M.

Let AB be the inclined Plain, P the Weight supported, DPV the Direction of the Force which supports the Weight. Tab. XX. Fig. 3. Let PC be drawn perpendicular to AB; and from the Point C, let CB be drawn parallel to the Horizon; and perpendicular to the common Section of the Plain and the Horizon, meeting the Plain in B; and CA perpendicular to the Horizon and also to CB, meeting the Plain in A, and the Line in which the Force acts in V.

Now P may be conceiv'd to be held unmoved by three Forces acting together: one of which is the Force of the Weight it self tending downwards in a Line parallel to VC; the Second is the Force acting in the Line DPV, and the Third is the Resistance of the Plain it self, acting in the Line CP perpendicular to the Plain: But these three Forces are to each other (*from what was said before*) as the Sides of the Triangle VPC; as will be evident, by drawing a Line through P parallel to VC, and compleating the Parallelogram. The Force therefore is to the Weight which it sustains, as PV to VC; that is, as the Sine of the Angle VCP, or ABC, to the Sine of the Angle CPV or CPD. *Q. E. D.*

Coroll.

1. If the Points V and A coincide, that is, if the Force acts according to the direction BA, the Angle CPD will be a right Angle; and therefore in that Case, the Force is to the Weight, as the Sine of the Inclination of the Plain, to the Radius, or as the Height of the Plain AC, to its Length AB. And in this Case, the Force which is requir'd to support a given Weight is least of all; because the Proportion of the Sine of the Inclination of the Plain, to the Radius; is less than its Proportion to any other Sine whatsoever.

2. If the Point V falls above A; the greater the Angle APV is, so much the more Force is necessary to support the given Weight upon the Plain AB. Insomuch, that by increasing the Angle APV, the Proportion of the Sine of the Angle ABC, to the Sine of the Angle CPD, is also increased, 'till PV, AV, become parallel, and the Angles VCP, CPD for that Reason equal, the Force and the Weight will also become equal.

3. So likewise, if the Point V falls below A, as at *v*, the Force requisite to support the given Weight, is again increased; the Angle *v*PA being increased, till P*v*, *v* C become equal, and then the Force and the Weight will become equal again. Further, when the Lines P*v*, PC coincide, and the Angle *v*PC by that means vanishes, the Sine of the Angle ABC will bear an infinite Proportion to the Sine of that; that is, no finite Force whatsoever, acting in a Line perpendicular to the Plain, will be able

to

ficient to consider those which we have occasion for in the explaining any Difficulties; herein imitating Geometers,

to support the Weight upon the Plain.

4. If the Line in which the Force acts be parallel to the Base of the Plain, the Weight is to the Force which supports it, as BC to CA, or as the Base of the Plain to the Height of it.

5. If from the Point P, PF be let fall perpendicular to
Tab. XX. BC, and from the Point
Fig. 4. C, CG perpendicular to
VP; it will easily appear, that PV is to VC (that is, the Force is to the Weight) as CF to CG. Wherefore the Force and the Weight will then support one another upon an inclined Plain, when they are to each other reciprocally as Perpendiculars drawn from the Point C to the Lines in which they act; (or, if GCF be looked upon as an angular Ballance moveable about the Center C) reciprocally as the Velocities of the Points G and F reckoned upon the Lines in which the Forces act.

Of the Wedge. Prop. 3.

If three Forces acting together upon an Isosceles Wedge, in Lines perpendicular to the three Plains of the Wedge; two of which Forces, *viz.* those acting upon the Sides are equal to each other, and the Direction of the Third which acts upon the Base of the Wedge, passes through its Vertex; if, I say, these three Forces support each other, the Force acting upon the Base, will be to the other Two, as the Base of the Wedge, to the Sum of its Sides.

D E

Let ABC represent a Wedge; and let CG be perpendicular
Tab. XX. to AB, and GD, *Gd*
Fig. 5. perpendicular to AC, BC; and these will be the Directions of the three Forces. In the Lines GD, *Gd* produced, let DE and *de* be taken equal to each other, which may therefore represent the two equal Forces, which act upon the Sides, in the Directions ED, *ed*. Let EF, *e f* be drawn parallel to AB, and DF, *df*, parallel to GC, so as to form the Triangles DEF, *def*. Now each of the Forces ED, *ed*, may be imagined to be resolved into two other Forces, which are to each other as EF to FD, and *ef* to *fd*: And to act in those Lines: And those two, which are as EF, *ef*, because they are equal, and opposite, will destroy each other. But the Force which acts upon the Base AB, in the Line GC; because it supports the two other Forces FD, *f d*: both which are the same way, and act in a contrary Direction to that Force upon the Base; is therefore equal to the Sum of them. The Force therefore acting upon the Base of the Wedge, is to the Sum of the Forces acting upon its Sides as DF + *df* to DE + *de* or (*by the similar Triangles*) AG + GB that is AB to AC + CB.

Coroll.

The Velocities of the Wedge, and of the Body resisting it, reckoned in the perpendicular Direction before explained, are to each other reciprocally as the Force acting upon the Base, to the Force acting upon the Sides of the Wedge, when these Forces are in *æquilibrio*.

For when the Wedge ABC is driven up to the Top, or is in the Situation *a b c*, it Tab. XX.
is evident, that the Parts Fig. 6.
of the Body that is cleaved, have receded from each other, the Length *g d* or GD, in the Direction of the Line perpendicular to AC or *a c*; GC therefore is the Velocity of the Wedge, and Gd the Velocity of the resisting Body. But (*by the similar Triangles*) GC is to GD, as AC to AG, that is, as AC + CB to AB. And the Proportion will be evidently the same, whatever Situation the Wedge be in, between the Parts of the Body to be cleaved by it.

ters, who do not draw from one Point all the Lines that can

Of the *Screw*.

A Definition.

If the Plain of the Triangle ABC (whose Hypothenuse represents such an inclined Plain, as was explained above in the 2d Proposition) be conceived to be so fitted to the Concave Superficies of a hollow Cylinder (the Circumference of whose Base is equal to the Line BC) that, the Plane ABC coinciding with the Superficies of the Cylinder, the Line BC may be bent into the Peripbery of a Circle equal and parallel to the Circumference of the Base; the Line BA will form a kind of Spiral, ascending upon the Cylindrical Superficies, and surrounding it once: So likewise, if several Planes, such as A *a c*, equal and similar to the former, and whose right Angles are subtended by the Line BA produced, be imagined to be fitted in the same manner, to the same Superficies, distant from each other, by the Space AC or *a c* (their common Height) there will be many Spirals formed by the Lines A *a*, &c. all continued from one to another, and each of them once surrounding the Cylindrical Superficies. Further, if other Planes similar and equal to ABC be conceived in the same manner to be fitted to the gibbous Superficies of another Cylinder, whose Base is equal to the Base of the Concave Superficies of the former Cylinder; there will by this means be Spirals formed in this gibbous Superficies, exactly like those in the Concave one before. Now if the latter Cylinder, which may be turned about its Axis, by means of a Leaver passing through the Center of any of its Bases, and lying in the Plane of that Base, be imagined to be so placed within the former Cylinder, which is fixed and immoveable, that the Superficies agreeing, the Spirals formed in each Superficies, may agree with one another also; and if it be so contrived, that they shall always thus agree, when the internal Cylinder is turned about its Axis, and its Base recedes from or approaches to the Base of the external Cylinder; it is evident, that two Screws, the Male and the Female may be conceived to be thus generated.

Tab. XX. Fig. 7.

Prop. 4.

In the Screw, as the Altitude of one Spiral, is to the Circumference of the Circle, whose Radius is the Leaver by which the internal Cylinder is turned round; so is the Force perpendicularly applied to the End of that Leaver, to the Weight lifted up by the Screw, when the Force and the Weight are in *æquilibrio*.

D E M.

Let the Axis of the Screw be perpendicular to the Horizon; and the Position of the Leaver, by which the internal Cylinder is turned about its Axis, will be Horizontal. Let the Weight be placed any where in the Line of the Axis; and then that Weight, by means of the internal Cylinder, will press with equal Force (in Directions perpendicular to the Horizon) upon every individual Point of the Spirals of the external Cylinder; and the Sum of the Forces with which all those Points are pressed, will be the same as the whole Weight to be lifted up. But let us first consider the Force, or that part of the whole Weight, which presses upon any one particular Point. Now it is easy to see, that the same Force, in a horizontal Direction, which is able to support the Weight, which presses upon any one Point of the Spiral, upon the inclined Plain of which that Spiral is formed; that same Force with the same Direction, is also sufficient to support that same Weight upon the Spiral; and that there is plainly no difference, whether this Force be immediately applied to the Point which is pressed; or be in any other Line touching the Base of the internal Cylinder. Let BC therefore be the Circumference of that Base; AC the Radius; AG the Leaver by which the internal Cylinder is turned about its Axis; FGH the Circle described by the Radius AG. These Things being supposed; from what has been said, together with the

Tab. XX. Fig. 8.

can be drawn from it, but ſuch only as they think may be of uſe in their Demonſtrations.

the Definition of a Screw, and the 4th *Coroll.* of the 2d Prop. it follows; that, as the Height of one Spiral, to the Periphery BC; ſo is the Force applied to the Point C, in a Direction perpendicular to AC, to that part of the whole Weight, which that Force ſupports upon any one point of the Spiral. And (*by the Property of the Leaver*) as the Circumference BC, is to the Circumference FH; (that is, as AC to AG;) ſo is the Force exerciſed in G to the Force exerciſed in C; becauſe the Directions of theſe Forces being parallel, they have equal Power on the Leaver ACG, whoſe Center is A. Therefore (*equally by Perturbation*) as the Height of one Spiral, to the Periphery FH; ſo is the Force which exerciſed in G, ſupports that part of the whole Weight, by which any one Point of the Spiral is preſſed; to that part of the Weight it ſelf: And as the Force which ſupports that one particular Part of the whole Weight, is to that one particular part of the Weight; ſo is the Force which, acting in the ſame Direction, ſupports all the Parts of the Weight, that is, the whole Weight; to all thoſe parts together; that is, to ſupport the whole Weight. Therefore, &c. Q. E D.

Coroll.

The Circular Velocity of that Force by which the Screw is turned round, and the Velocity of the Weight which is lifted up by means of the Screw, are to each other reciprocally as thoſe Forces when they are in *æquilibrio*. For it is evident, that in a whole Revolution of the Leaver, the Weight is raiſed juſt the Height of one Spiral, and that in every Part of the Revolution, the Weight is raiſed proportionably.

Of the Pulley or Windleſs. Prop. 5.

It is evident, that the Pulley may be accounted for, in the ſame manner as the Ballance or Leaver, in which the Forces are imployed either on the ſame Side of the Center, or on both Sides: Which, when they are in *æquilibrio*, are to each other reciprocally as Perpendiculars let fall from the Point which repreſents the Center of the Leaver, to their Directions. And hence the Forces of Engines, which conſiſt of many Pulleys, according as they are differently framed, may eaſily be explained. If the Compoſition of the Pullies, or the manner of framing the Windleſs be ſuch, that the Ropes which are fitted to the Pullies, are parallel to one another; and the Weight be ſo ſuſpended in the midſt of the Ropes, as to draw every one of them with equal Force; it is ſelf evident, that the Force, is to the Weight which it ſupports; as One, to the Number of Ropes. For when that Force is applied to one of the Ropes only, it is directly oppoſed to that part only of the whole Weight, which draws that Rope; the Pin to which the Windleſs is fixed, ſupporting the other Parts of the whole Weight.

It is alſo evident, that in this Engine, the Force and the Weight, when they are in *æquilibrio*, are to each other reciprocally, as their Velocities, when the Force raiſes the Weight. For it is manifeſt, that theſe Velocities are to each other, as the Decreaſe of the Length of all the Ropes which ſupport the Weight taken together, to the Increaſe of the Length of the Rope to which the Force is applied, in the ſame time; and that juſt ſo much as is loſt in a given time in *all* the Length's of the Ropes which ſupport the Weight; the very ſame is gained, in the ſame time, in the *one* Length of that Rope to which the Force is applied.

CHAP.

CHAP. XV.

Of Reflexion and Refraction.

1. What is meant by Reflexion and Refraction.

THAT we may apply what has been ſaid to ſome Advantage, we ſhall, by the help of it, explain the Manner of *Reflexion* and *Refraction.* But to avoid the Error of the Antients, who confounded theſe two Things together, we may obſerve; that by *Reflexion* is meant nothing elſe but the Bending, or Alteration of the *Determination,* when a Body in Motion, ſtrikes againſt another Body which it cannot penetrate; and by *Refraction* is meant the Bending or Alteration of the *Determination,* when a Body in Motion, paſſes out of one *Medium* into another, which receives it with more or leſs Difficulty.

2. An Inſtance of Reflexion. Tab. II. Fig. 6.

2. Suppoſe, for Example, that the Body A, which is perfectly hard, moves with a ſimple Motion, in the Line AB, and that it meets with the Body CDEF, which I ſuppoſe to be perfectly hard likewiſe, and not to be ſhaken: Then, from what has been ſaid, it follows, that the Body A [1] ought to continue in Motion, becauſe it does not communicate any part of its Motion; and it ought to be ſtruck back, becauſe it cannot go on in a ſtreight Line: But let us ſee how, and which way: And that we may not multiply Difficulties, we do not now conſider, what will ariſe from its Bigneſs, Figure or Gravity: Let us ſuppoſe likewiſe, that the Air makes no Reſiſtance to it, and that it moves with equal Velocity.

3. That the Angle of Reflexion is equal to the Angle of Incidence.

3. This being ſuppoſed, let a Circle be deſcribed on the Center B, and with the Diſtance BA; and for the ſame Reaſon that the Body A comes from the Circumference to the Center in a given Time, it ought to go from the ſame Center to ſome Point of the Circumference of this Circle in the ſame Time: Now to determine that particular Point; from the Points A and B, let the Lines AG, BH be drawn perpendicular to the Superficies CF; and the Line AHI, parallel to that Superficies: Now we may obſerve, that though the Body A is carried with a ſimple Motion, it is however true, that with reſpect to the Body CDEF, its Determination in the Line AB, is compounded of two others, the one of which makes it go towards the right Hand, by the Length of the Line AH,

1 *Ought to continue in Motion)* See above, Chap. x. Art. 13.

or

or which is equal to it, GB; and the other makes it come downwards towards GB, by the Length of the Line AG. Now we may further obferve, 1 that the Body CDEF refifts the Determination downwards, but that it does not at all refift the Determination towards the right Hand, that is, that part of the Motion which is determined towards the right Hand, which confequently 2 ought to continue as it began. So that the Body A having in a given Time with this Determination, paffed through the Space contained between the Lines AG, HB, that is, moved the Length of the Line AH or GB, it ought in the fame time to pafs through an equal Quantity again, or which amounts to the fame Thing, it ought at the End of this Time, to be found in the Line IL, which I fuppofe to be perpendicular to the Superficies CF, and the fame Diftance from HB, as HB is from AG. So that, to fatisfy that part of the Motion which is towards the Right, which does not alter at all, we find that the Body A in the given Time, ought to be fomewhere in the Line IL. But to fatisfie the whole Motion, we have before fhown, that it ought in the fame Moment to be fomewhere in the Circumference of the Circle: Therefore, that thefe two may be both fatisfied together, we ought to conclude, that it will at the fame Time, be in the Circumference of the Circle, and in the Line IL together, which can be no where elfe but in the Point I which is common to them both. Thus we fee the Body A which began to move in the Line AB, is reflected in the Line BI, which makes with the Superficies CF the Angle

Tab. II. Fig. 6.

1. *That the Body CDEF refifts the Determination*) If the incident Body A, and the Body CDEF upon which it ftrikes, are void of all Elafticity; the Body CDEF not only refifts this perpendicular Determination, but entirely deftroys all the Motion that arifes from that Determination (See *the Notes on Chap. x. Art.* 13.) fo that the Body A, is afterwards moved, with the other part of its Motion only, along the Superficies BLF. But if either, or both thefe Bodies be perfectly elaftick, then a new Motion will be impreffed upon the Body A, equal to the Motion which was loft, and with a *contrary* Determination; fo that, when it comes to the Superficies GL, with the Determination AG, it will then recede from it with the Determination LI. This is carefully to be obferved, becaufe it is neceffary to the compleating this Demonftration, by which it appears, that the Angles of Incidence and Reflexion are equal. For the Nature of this *Elaftick Force* being rightly underftood, the Demonftration concerning the reflecting of Elaftick Bodies, will hold in the fame manner as in perfectly *hard* Bodies, according to the Author's Principles. See further, *the Notes on Chap.* xi. *Art.* 6. Tab. II, Fig. 6.

2. *Ought to continue as it began*) Hence it follows, that the Lines of Incidence and Repercuffion are in a Plane perpendicular to the Superficies of the reflecting Body. See *the Notes on Chap. xxxiv. Art.* 2.

IBL, which is called the *Angle of Reflection*, 1 which may easily be demonstrated to be equal to the Angle ABG, which is called the *Angle of Incidence*.

4. An Example of one Sort of Refraction. Tab. III. Fig. 1.

4. Let us now come to *Refraction*; and that we may explain the Nature of it fully, I shall here make use of the Example of a Ball, as was before done in Reflexion. Suppose then the Ball A to be moved along the Line AB in the Air, but striking obliquely upon the Water below CD, instead of going on directly towards E, it tends towards F; this Sort of bending, 2 measured by the Angle EBF is what we call *Refraction*.

5. Another Sort of Refraction. Tab. III. Fig. 1.

5. If the Body A, after it is arrived at B in the Line AB, instead of being turned towards F, is turned towards G; this is *Refraction* also, but of a different Sort from the other: Now in order to distinguish these two Sorts of *Refraction*, let the Line HB, be drawn through the Point B, where the Body A passes out of one Medium into the other, perpendicular to the Superficies CD, which divides the two Mediums, and the Kind of *Refraction* is determined, by the Approach to, or Recess from this Perpendicular. For Example, if the Body which moves along the Line AB, when it is turned out of the way, afterwards moves along the Line BF, this is called *Refraction from the Perpendicular*; but if it afterwards moves along the Line BG, then it is called *Refraction to the perpendicular*.

6. When a Body is turned out of its Course, we must think, that it meets with some Obstacle on that part from which it turns.

6. These two Sorts of *Refraction*; have been observed a long time, but the Cause of them was not at all known. And we may venture to say, that this is one of those Things which the Antients were ignorant of, and the Discovery of which is owing to one of the principal Men of this Age; and agreeable to his Opinion, I thus explain this Matter: Since we are sure, that every Thing, as much as it can, persists in that State in which it is; after we find by Experience, that a Body quits the streight Line in which it began to move, we must necessarily think, that it has has met with some Obstacle on that part from which it removes: Thus, if, when the Body A is come to the Point B, it is turned out of its Course towards the Point F, we ought to conclude, that it meets

Tab. II. Fig. 1.

1. *Which may easily be demonstrated*) For BL = GB by the Hypothesis; and LI = GA, because GL and AI are parallel, and the Angles L and G are right Angles, by the Hyp. Therefore the Triangles ILB, AGB are equal and similar. (Tab. II. Fig. 6.)

2. Measured by the Angle EBF) *See the Notes upon Art. 11. of this Chap.*

with

with more Reſiſtance on the Side M, than on the Side N; and if it is turned toward G, we have Reaſon to think, on the contrary, that it has met with more Reſiſtance on the Side N, than on the Side M.

7. We may reaſon in the ſame manner, in order to determine on which Side, a Body moving out of one *Medium* into another, will be turned. For ſince we before knew, that the unequal Reſiſtance, which a Body in Motion meets with on different Sides, (according to the different *Mediums* through which it paſſes) would force the Body to turn out of its Courſe, and to remove from that Side where it finds the moſt Reſiſtance; when once we come to know, that there is more Reſiſtance on the one ſide than the other; we conclude, that it will turn out of the way, by removing from the *Medium* where the Reſiſtance is greateſt. And thus when we once come to know that Water reſiſts the Motion of a Ball more than Air, we ought to think, that the Ball which moves in the Air from A to B, in paſſing into the Water which is below B, will turn towards F, and ſo will recede *from the Perpendicular*.

7. That the Body in Motion, recedes from the Medium which makes the greateſt Reſiſtance to it.

8. This may be applied [1] to all ſorts of Bodies, and to all ſorts of *Mediums*, and therefore we may lay it down for a general Maxim, that when a Body paſſes obliquely out of one *Medium* into another, which makes a *greater* Reſiſtance to it; it ought ſo to turn as to remove *from the Perpendicular*; and, on the contrary, when it paſſes out of one Medium into another, where it finds *leſs* Reſiſtance; it ought to be ſo turned, as to approach *towards the Perpendicular*.

8. The Way how to determine the particular ſort of Refraction.

9. I expreſly added, that the Body which paſſes out of one *Medium* into another, muſt fall *obliquely* upon the Superficies which ſeparates the two Mediums, in order to be refracted; for if it falls perpendicularly upon this Superficies; as there is nothing to reſiſt its Motion more on the one ſide than on the other, ſo it ought not to be turned out of its courſe at all, [2] but to continue to move in the ſame Line.

9. That a Body which falls perpendicularly upon another, ought not to be refracted at all in entring into it.

10. The

1. *To all Sorts of Bodies*) For this Reaſon the Rays of *Light* which paſs out of Air into Water, are reflected *towards the perpendicular*, contrary to what we ſee in a *Ball* thrown out of our Hand; becauſe Water which reſiſts the Motion of the *Ball* more than Air, on the contrary, reſiſts *Light* leſs. (*See Chap. 27. Art.* 38.) or to ſpeak more truly, it accelerates the Motion of Light more by attracting it; as will be ſhown afterwards.

2. *But to continue to move in the ſame Line*) Yet ſome have thought, as *J. Voſſius, Willebrord Snell*, that they have ſeen a perpendicular Ray of Light, ſome way refracting and con-

tracted

10. *An Example of the Motion of a refracted Body.* Tab. III. Fig. 1. 10. The Exact Quantity of the Refraction of a Body passing *obliquely* out of one *Medium* into another, may be determined, provided we know how much the one Medium resists its passing more than the other. Suppose, for Instance, the Line CD separates the two Mediums, the upper one of which is Air, and the under one Water, and that the Water resists the Motion of the Ball A twice as much as the Air; then let us imagine, that this Ball has run the Length of the Line AB with such a Velocity, as takes up a Minute, and is then ready to enter the Water obliquely: and that the Thing may be the easier apprehended, we meddle not with what might happen on the account of the Bigness or Weight of the Ball. Let us imagine further, that its Motion in the Air has been all along uniform, and that after having lost half its Velocity by meeting with the Superficies of the Water, it loses no more, though it sinks never so deep; for the Deviation [1] is made only in the Superficies, and the Water which resists all its Parts equally, can only make the Ball take up more or less Time in moving through a given Line, and not cause it to move out of it.

11. *How Refraction is made.* Tab. III. Fig. 2. 11. This being supposed; having described a Circle on the Center B, and the Distance AB, let us consider, that the Ball having taken up a Minute of Time in moving from the Circumference of the Circle to the Center, where it loses half its Velocity, ought afterwards to take up two Minutes in moving from the Center to any Point in the Circumference: Now in order to determine where this Point ought to be, we observe; that though the Motion of this Ball was supposed to be a simple Motion, yet its Determination in the Line AB, with respect to the Superficies of the Water, is really composed of two Determinations, one of which causes it to move from the Left to the Right, the Length contained between the Lines AF and BG, which are perpendicular to the Superficies of the Water, that is, the Length of the Line AG or FB; the other Determination makes it descend downwards the Length contained between the two Parallels AG, CD, that is, the Length of the Line AF. We must further

tracted into it self; which is, because when we look upon any Thing in the Water, it seems to be nearer us than it really is; so that herein they falsely ascribed that to Refraction (of which there is none in the perpendicular) which was to be ascribed to the diverging of oblique Rays after Refraction, from the Point nearest to us. But for the real and manifest Refraction of perpendicular Rays, which is made in *Island Chrystal*, See *Newt. Opt. pag.* 229.

2 *Is made only in the Superficies*) It is otherwise in the Reflexion and Refraction of *Light*. *See below, Chap.* xxvii. *Art.* 35. 37.

observe,

observe, that the Superficies of the Water resists the Determination downwards, which consequently must be altered; [1] but it makes no Resistance at all to the Determination from Left to Right, wherefore this will not be at all altered, but the Ball which moved in this manner the Length FB during rhe Minute which it took up in going from the Circumference of the Circle to the Center, ought to move twice this Length in two Minutes, in going from the Center to the Circumference: Let BL therefore be taken equal to twice BF, and the Line ELM drawn perpendicular to CD, and the Ball ought to be found somewhere in this Line, two Minutes after it has parted from B; but it was before said, that it ought at the same time to be in the Circumference of the Circle also; whence we conclude, that the Ball will be at the same time in this Line, and also in the Circumference of the Circle; that is, in the Point M, where they intersect each other. So that instead of continuing its Course in the Line AB produced to N, it will be carried along the Line BM, which is *from the Perpendicular,* [2] and the Refraction will be measured by the Angle MBN. From what has been said, it is plain, that if the lower Medium had resisted the Ball *less* than the upper one, the Refraction ought to have been contrary, that is, *to the Perpendicular*.

12. Without altering any Thing before supposed as to the Difference of the Resistance of the two *Mediums,* and the Velocity of the Ball, let us now suppose, that the Ball, in order to go to the Point B, comes from another Point more distant from the Point P than was supposed in the former Example, so that the Line FB which is the Measure of *the Determination towards the right Hand* be longer than half the Radius of the Circle, and consequently the Line BL, which is twice as long, be longer than the whole Radius; it ought to follow, according to the foregoing Reasoning, that the Line ELM will fall without the Circle, and not intersect it at all; And so our

12. The difficulty there is when the Ball falls very oblique.

Tab. III. Fig. 3.

1. *But it makes no Resistance*) But it does resist that Determination als[o], as it enters; for the Ball in entring, strikes or rubs against the farther part of the Hole which it enters into: for which reason, and because the Motion of the Ball is afterwards perpetually retarded as it passes through the Water which resists it, this Instance is not sufficiently accommodated to explain accurately and mathematically the Nature of Refraction.

2. *And the Refraction will be measured*) It is a right Observation of *Cartes* here, that Refraction *universally* and *in all Incidencies* is to be measured by the Proportion of the Lines AG and OM, and not by the Angles ABG, and HBM, or NBM. *See Cartes's Dioptr. Chap. 2. Art. 7.*

Tab. III. Fig. 2.

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Argument seems to conclude, that the Ball ought to be in two different Places at the same time, *viz.* in this Line, and in the Circumference of the Circle; which is impossible.

13. That a Body which falls too oblique upon another, ought not to penetrate it at all.

13. It must be confessed, that here is some Mistake, whencesoever it arises; for every Argument that leads to an Impossibility, is defective either as to the Form or as to the Matter of it. But let us not imagine that there is any Fault in the Form of this Argument which seems to conclude in an Impossibility; let us rather say, that it being conclusive, it is a certain Sign, that the Fault was in some of the Suppositions that were made. And so indeed it was, for we supposed that the Ball, when it had lost half of its Motion by meeting the Superficies of the Water, would enter into it, though it fell never so oblique, which is not so. For we see by Experience in a Sea-Fight, that Cannon-Balls which are shot too oblique upon the Water, are reflected by the Superficies of the Sea, and kill the Soldiers upon the Decks of the opposite Ship. And we observe the same Thing in Stones which Children make Ducks and Drakes with in the Water.

CHAP. XVI.

Of hard Bodies put into Liquors.

1. That the Position of hard Bodies put into Liquors is an Effect of Motion.

ALL than can be said of the Place which a Body ought to possess in any Liquor according as it is more or less heavy, does properly belong to the Doctrine of Motion. For these Bodies are in Motion when they sink in the Liquor, and they are in Motion also when they rise from the Bottom, to the Superficies.

2. That the Superficies of a heavy Liquor contained in a Vessel, ought to be level. Tab. III. Fig. 4.

2. That we may not pass by any Thing therefore which may be of use afterwards, let ABCD be a Tub filled with Water, and suppose first, that this Water is upon the Level, that is, no one Part of the Surface AD higher than another; then imagining it to be divided into a great many Columns, perpendicular to the Bottom of the Tub, let us examine one of these Columns, as EFGH. And first it is observable, that though this whole Column endeavours to sink down, yet it cannot, because the smaller Columns, into which this may be subdivided, must bend at the Bottom of the Vessel before they can return up-

upwards; but that they cannot do, becauſe they meet and ſupport each other, and are alſo ſupported by the little Columns on all Sides of them, which tend downwards likewiſe, and with equal Force. So that the Water in the Tub ought to continue [1] upon the Level, and to remain in perfect Reſt and *Æquilibrio*, if there be nothing elſe but its own Weight to move or ſhake it. Whence it is manifeſt, that if we ſuppoſe the Water in the Tub to be higher in one Place than in another, that it cannot continue ſo, becauſe thoſe little Columns of Water which are longer than the other, will have more Power to deſcend than they, and will never leave crouding them up, till the Surface of the Liquor is come to a Level, when they will all be in *æquilibrio* with each other. Therefore when a heavy Liquor is contained in any Veſſel, we are to think that its Weight diſpoſes the Surface of it to be upon the Level, and that it will continue ſo, unleſs altered by ſome foreign Cauſe.

3. Let us conſider further, that if there be put into the Water in this Tub any hard Body, ſuch as I, of equal Gravity with the Water; as its Weight would have neither more nor leſs Effect than the Water whoſe Place it poſſeſſes; there is no Reaſon why any Alteration ſhould be made in the Column EFGH, ſo that the Body I muſt continue where it was placed. *3. That a hard Body put into a Liquor of equal Gravity, ought to reſt in any part of it.*

4. But if we imagine this Body to be heavier, by an Ounce, ſuppoſe, than a Quantity of Water of equal Bulk; it is manifeſt then, that all the Columns of Water will not be in *æquilibrio*, but the Body will go to the Bottom, not with its ordinary Weight, but only with the Difference betwixt that and the Weight of a Quantity of Water of equal Bulk, that is, with the Force of an Ounce Weight. *4. With what Force a Body which is heavier than Water, ought to ſink to the Bottom.*

5. But ſince Water was here taken only for an Example, and the Reaſoning holds the ſame, when applied to any other heavy Liquor; we may affirm in general, that in ſupporting a heavy Body, we ought only to feel the Exceſs of its Weight above that of an equal Bulk of the Liquor in which it is. Hence it is, that we are not ſurpriſed to find by Experience, that a pretty luſty young Man who weighs a Hundred and thirty eight Pound in the Air, does not weigh above eight Ounces in the Water. But we have before ſhown, by many Experiments, *5. That we cannot feel the real Weight of any Body by our Senſes.*

1. *Upon the Level*) That is, as to the Senſe. But in reality it is part of the Sphærical Superficies of the Earth.

that the Air itſelf is heavy, wherefore we do not by our Senſes feel the true Weight of a Body in the Air, but only the Difference of the Weight of the Body and of the Air; and conſequently, unleſs we are under any particular Indiſpoſition, we ought never to feel our ſelves lighter, but only when the Air is heavier.

6. That a Body which is lighter than the Liquor, ought to riſe up, and that with ſome Force. Tab. III. Fig. 4.

6. It is evident, that if the Body I, juſt now mentioned, had been ſuppoſed lighter than the Bulk of Water, whoſe Place it poſſeſſes; the Column EFGH would not be heavy enough to be in *æquilibrio* with the reſt of the Water in the Tub; wherefore this Column will be forced to give way, till the Body I be got up to the Surface AD, beneath which, ſo much of it will remain, as poſſeſſes the Place of a Quantity of Water equal in Weight to the Body.

7. How to find whether a hard Body weighs more or leſs than an equal Bulk of any Liquor.

7. From what has been ſaid, we draw two very important and uſeful Inferences. Firſt, *That if a Body put into any Liquor, ſinks to the Bottom, it is certain that Body is heavier, than an equal Bulk of the Liquor, but if it ſwims on the Top, it is an infallible Sign, that it is lighter.*

8. The way to find which is the heavieſt of two Liquors.

8. Secondly, *If a hard Body be put into two Liquors, and riſes in the one, but ſinks in the other, the former muſt neceſſarily be heavier than the latter* *.

9. This

* It is worth while to explain, a little more fully, and in better Order, the Hydroſtatick Propoſitions, which are urged too briefly and confuſedly in this Chapter.

1 Therefore *All Water gravitates in every Place, even in Water it-ſelf* (and the ſame is to be underſtood of any other Liquor) *and by reaſon of the equal Preſſure of its Parts on all Sides, its Superficies ought to be plain and level.* This is demonſtrated *in the ſecond Article of this Chapter,* and by the famous Mr. *Boyle in his Hydroſtaticks. Paradox* 1.

Tab. III. Fig. 4.

2. *A hard Body, ſuch as* I, *equal in Weight to a Quantity of Water of the ſame Bulk, put into Water, ought neither to ſink nor riſe, but to reſt in any Place.* For the Column EFGH gravitates neither more nor leſs than the Columns which ſurround it, and therefore it ought to keep in *æquilibrio*. See *Art.* 3. *of this Chap.*

3. *A Body, ſuch as* I, *heavier than Water, ought to ſink in the Water.* Becauſe then the Column EFGH is heavier than the Columns which ſurround it. See *Art.* 4. *of this Chap.*

4. *A Body, ſuch as* I, *heavier than Water, ought to have juſt ſo much Weight in Water, as it exceeds in Weight an equal Bulk of Water.* For ſince the Body I poſſeſſes the Place of an equal Bulk of Water in the Column EFGH; it is manifeſt, that by how much that Body exceeds that equal Bulk of Water in Weight, by juſt ſo much is that Column heavier than it was before. See *Art.* 4. *of this Chapter, and Archimedes of Bodies put into Fluids. Prop.* 7.

Hence, ſince the Proportion of Weight betwixt Gold and Water is known, Gold may be proved and valued, by Weighing it in Water. See *Boyle's Hydroſtatick Medicine.*

5. *Any Body ſuch as* I, *put into Water, is not only preſſed downwards by the incumbent* Water, but is alſo preſſed upwards by the Water that is under it. This is evident *from the firſt Propoſition.* See alſo *Boyle's Hydroſtaticks, Paradox* 3.

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9. This being so, if we examine the Opinion of some Philosophers, *viz.* that there are certain Places natural to all Bodies where they of themselves continue at rest, and have no Tendency to go out of them, and that this is the Rea-

9. A Mistake in some Philosophers.

6. *The heaviest Body of all, such as* I, *a Cube of Gold, if it be put so deep into the Water, that the Depth of the Water from EH to the lower part of that Cube be twenty times as much as the Thickness of* I *is, that Cube will be so pressed up wards by the Water that is under it, that, if the incumbent Water* EIH *were removed, it would not sink.* For since the Cube I is just of the same Weight as the Water which reaches from EH to the Bottom of the Cube; all which Water we now suppose to be removed; it is evident, that the Column FIG in this Case, is in *æquilibrio* with the Columns which surround it, and therefore the Cube I cannot sink. See *Hydrostatick Parad.* II.

7. *A Body, such as* I, *lighter than Water, let it be pressed never so much by the incumbent Water, ought to rise notwithstanding.* For in this Case, the Column EFGH is lighter than the Columns of Water which surround it. See *Art.* 6. *of this Chap.*

8. *When a light Body is risen to the Top of the Water, so much of it ought to remain under the Water, as is equal to a Bulk of Water weighing as much as the whole Body.* This is the Fifth Proposition of *Archimedes concerning Bodies put into Fluids*, and is easily demonstrated from what has been already said. For it is manifest, that when the lower Part of the Body swimming in the Water, is sunk in this Proportion, the whole Column EFGH is in *æquilibrio* with the Columns that surround it; and if the same Body be sunk deeper, this Column will be lighter than the rest of the Columns; if not so deep, it will be heavier.

Tab. III. Fig. 4.

9. *In every Body that is lighter than Water, the Proportion of its Weight to the Weight of Water, is as that part of it under the Water to the whole Body.* This Proposition follows from the preceeding one, and is more at large demonstrated by *Archimedes, Book* II. *Prop. of Bodies put into Fluids.*

10. *All Water presses upon the Bodies under it, in proportion to its perpendicular Height, and not in proportion to its Breadth.* This noble Proposition is at large demonstrated in *my Notes upon Chap.* 10. *Art.* 11.

11. *This Pressure acts upon Bodies immersed in the Water, not only on the Top, but on the Bottom and the Sides, every way equally.* This Proposition follows from the foregoing one, and is demonstrated from the Nature of Water, whereby every Pressure is propagated equally, and entire every way. See also *Boyle's Hydrost. Paradox* 7.

12. Hence, *a wooden Trencher put under Water, immediately rises up; though there be a much greater Quantity of Water lying above it, than is under it; neither is there any such Thing in Nature as Levity, to lift it up.* This Proposition you have demonstrated in *my Notes on Chap.* X. *Art.* 11. *Coroll.* 3.

13. However, *If the wooden Trencher be exactly fitted to the Width of the Vessel, so that no Water can get in between it and the Sides of the Vessel, which by communicating its Weight to the Water beneath, might force the Trencher up; or if the Trencher goes so close to the Bottom of the Vessel, that no Water can get in betwixt it and the Bottom, then the Trencher will not rise at all.* Which is a manifest Proof, that there is no such Thing as *Levity* in Nature. See *the same Place.*

It is very hard to prove this Proposition by Experiments, because Water is so apt to wet and run all about. But I have tried it with Quicksilver, which will not wet most Bodies; for after I had gently put a Piece of Money on the Bottom of a Vessel full of Quicksilver, the Money did not rise up; but if I shaked the Vessel, or lifted up the Money ever so little with a Needle, that some of the Quicksilver might get betwixt the Money and the Bottom of the Vessel, the Money was immediately raised up.

Reason why Water has no Weight in Water; we shall not scruple to affirm, that this is as gross an Errour, as it would be in a Man, who, seeing a large Canon in one Scale, and seven or eight thousand Pound Weight in the other, should affirm, that the Canon did not weigh any Thing in this Place, because he can easily lift it up or down: For this Opinion of these Philosophers is founded upon this Experiment, that in drawing Water out of a Well, we do not begin to feel the Weight of that with which the Bucket is filled, till it comes into the Air; whereas they ought to think, that as the Canon is always heavy, and we could not easily lift it, but for the Weight which keeps it in *æquilibrio*; so also the Water weighs always the same; and the Reason why we don't perceive its Weight when the Bucket is under Water in the Well, is, because we are assisted by the rest of the Water in the Well, which is in *æquilibrio* with that in the Bucket.

14. *It is possible for VVater to depress and sink a Body lighter than it self.* This may be done by gently putting the Syphon ABCD, filled with Oyl as high as ABC, into the Water till the shorter Arm AB be under Water; for then the Water pressing upon the Superficies AB, will lift up the Oyl so much the higher towards D, as the Syphon is let down deeper into it. And from hence also it is as clear as the Sun at Noon-Day, that there is no such Thing as *Levity* in Nature. But lest the Experiment should fail by the Oyl's mixing with the Water, it is more proper to use a Syphon with smaller Arms. See *Boyle's 8th Hydrostatick Paradox.*

Tab. I. Fig. 4.

15. So likewise, *it may be, that Oyl having VVater on each Side of it may not rise up*, viz. thus; if, when the Syphon is filled with Water up to ABC, Oyl be poured upon the Water in each Arm, and Water be again poured upon that Oil to ballance the Pressure of the lower Water upwards. See *Boyle's Hydrostaticks, Paradox* 9.

CHAP.

CHAP. XVII.

Of Accretion, Diminution, and Alteration.

AS *Aristotle* in treating of *local Motion* considers also the other Changes that happen to natural Bodies, such as *Accretion, Diminution and Alteration*, which he calls Motion likewise; so we after his Example, shall not wholly neglect these, but show that it was not without Reason, that he brought them under this Head, since they are indeed the Effects of *local Motion*. All the World agree, that by *Accretion* and *Diminution* is meant the sensible Increase or Decrease of the proper Substance of a Body; Thus we are sure, that the Trunk of a Tree is increased when we see it bigger than it was before. *1. What is meant by Accretion and Diminution.*

2. Since we observe, that Trees, and in general all Bodies stand in need of Nourishment, to make them increase, and that it is impossible to conceive how a Body should increase and become bigger without some Parts being added to its former Bigness; this is a convincing Proof, that every Body which increases, receives some Augmentation of Matter. And as this is true of a Body which increases, so may we also affirm, that every Body which decreases, loses some of the Matter which it had before. *2. How Bodies are increased and diminished.*

3. However this does not hinder us from making a Difference betwixt *Increase* and *Rarefaction*; and betwixt *Decrease* and *Condensation*: For the Matter which is added to a Body increasing, and That which is taken from a Body decreasing, is looked upon as belonging to it, and as part of its proper Substance; but, as was before observed, the Matter which enters into the Pores of a Body to rarify it, or That which gets out of its Pores, that it may be condensed, is looked upon as Matter that does not belong to it. *3. That Increase is different from Rarefaction.*

4. The Idea we have of the *Accretion* of a Tree, being different from the Idea we have of its being transplanted, it must be owned, that *Aristotle* had Reason to make a difference betwixt *Accretion* and *local Motion*. However, as a Tree cannot be transplanted, but by the local Motion of its whole Body, so we cannot conceive how it should increase but by the local Motion and *4. That there is a great deal of difference betwixt Accretion in a Body, and the local Motion of it.*

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Union of the ſmall Particles which contribute to the increaſing it.

5. *How Bodies are altered.* 5. When a Body neither increaſes nor decreaſes, but is ſomewhat changed, if this Change be not ſo great that we do not at all know it; we call it, as was ſaid before, *Alteration*; hence it is eaſy to ſee; that there can be no *Alteration* without *local Motion*: For how can there be any Change in a Body, if none of the Parts which compoſe it, and upon the particular Order of which its Nature depends, have changed their Situation? This being ſo, it is very evident, that there muſt be an *Alteration* in a Body, when the ſenſible or inſenſible Particles of which it is compoſed, are put out of their Order, or any great Change made in their Figure: Or it may alſo ſuffer an *Alteration*, by the Acquiſition of ſome new Particles, or by the Loſs of ſome of its old ones; all which cannot be without local Motion: Thus, when there is an *Alteration* in a bruiſed Apple, we can eaſily imagine that many of its Particles have been forced to change their Situation, and perhaps ſome of them have alſo changed their Figure. If after this, any one ſtill doubts whether there may not be ſome kind of *Alteration* in which there is ſomething elſe beſides what proceeds from local Motion, I think he cannot be ſatisfied better, than by what we are now going to ſay of *Forms*.

CHAP. XVIII.

Of FORMS.

1. *That Forms ought to be treated of by themſelves.* FORMS are a Subject that we cannot hope to treat of, as we have done of *Matter*. For ſince *Matter* is a common *Subſtratum*, which, when once we underſtand what it is in Wood, we cannot at the ſame time but underſtand what it is in Fire, and in every Thing elſe; one ſingle Reflection is of it ſelf ſufficient to gain the Knowledge of it. But becauſe the *Form* of any Thing, is that which makes it to be that particular Thing, and diſtinguiſhes it from every Thing elſe; it does not follow, that if we know the Form of Wood, we therefore know the Form of Fire, or any Thing elſe. Wherefore if we would ſucceed herein, and ſay ſomething more than ordinary, we muſt deſcend to Particulars, notwithſtanding the Cu-

Cuftom of Philofophers, who feldom do fo, but for the moft part content themfelves with propofing abundance of loofe Queftions, which we may look upon as fuperfluous, and from which we can gain no Advantage.

2. Of fubftantial Forms, and that the Inftance of the rational Soul, does not prove that there are any others.

2. However, I do not affirm, that it is an ufelefs Enquiry, if it fhould be asked here, as ufually it is, whether there be any fuch Things as *Subftantial Forms*, that is, *Forms* which are real *Subftances*; and confequently have a diftinct Exiftence from that of Matter. But thus much at leaft, I may venture to affirm; that the Solution of this Difficulty, depends upon the particular Knowledge of the Things. The Inftance of *the rational Soul* proves nothing here; for though we know that this is a Subftance really diftinct from the Body, to which it is united, and that it does not at all depend upon it for its Exiftence, yet we can conclude nothing from hence as to the Forms of other Beings which are purely material.

3. That the rational Soul is not the Form of the humane Body as a Body.

3. But if we confider this Matter more clofely; though I acknowledge, as all the World do, that the *Soul* is that which particularly makes *a Man* to be *a Man*; and confequently that it is truly the Form of *a humane Body* as *humane*; yet I can't agree, that it is, properly fpeaking, the Form of all that which is fenfible, and is called the *Body* and confidered fimply as a *Body*; any more than it is the Form of any of its Parts, confidered as different from each other: For in this Senfe, every one of them has its particular Form fo clofely connected with the Matter of it, that it continues as long as the Part fubfifts, even after the Soul is feparated from the Body. And indeed after fuch Separation, every part appears the fame, as it did immediately before. For, that which was Flefh, for Inftance, is Flefh ftill, and that which was Bone, is Bone ftill, and fo of the reft.

4. An Error amongft Philofophers.

4. The Caufe of many People's Miftake, who confound the Properties of the Body with thofe of the Soul, is this; that a dead Body, when the Soul is feparated from it, is uncapable of many Functions which we obferved in it before, fuch as moving it felf, Refpiration, Nourifhment, *&c.* fo that they perfwade themfelves that all thefe Things depend upon the Soul, and would not have ceafed in the Body, if the Soul had not departed from it: Whereas we ought rather to think, that the continuing of the Soul in the Body, depends in fome meafure upon the Difpofition of the Body to perform thefe Functions, and that the Separation is a Confequence of thefe Functions not being able to be performed. For every Day's

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Experience ſhows us, that Death never comes, nor is the Soul ever ſeparated from the Body, till it is ſome way hurt, or by ſome Means ſpoiled and corrupted. And we have no Example of the Soul's being ſeparated from a ſound and perfect Body, and that this Body did not begin to be corrupted, till after, and becauſe the Soul was ſeparated from it.

5. That there are eſſential Forms. 5. It would therefore be unreaſonable, upon the ſingle Inſtance of the *Rational Soul*, which is very different from the common Forms of Bodies, and without firſt knowing the particular Form of all Kinds of Bodies, to affirm here raſhly, that there are *ſubſtantial Forms* in Things merely corporeal; however we may venture ſafely and confidently to aſſert, that there are ſome Forms which are *eſſential*, that is, ſuch as belong neceſſarily to their Subjects: Thus *to be liquid* is eſſential to *Water*, becauſe there is no Water which is not liquid; we may alſo affirm, that there are other *Forms* which are only *accidental*, becauſe they ſo belong to the ſubject, that it can exiſt without them, and not ceaſe to be what it was. Thus *coldneſs* is an *accidental* Form of Water, becauſe Water would ſtill be Water, if it was made hot.

6. That it is not certain that Ariſtotle *did allow of ſubſtantial Forms.* 6. It might very eaſily be, that *Ariſtotle* might acknowledge *eſſential Forms* and not *ſubſtantial Forms*; for it is certain, that the *Greek* Word which he uſes, may as well or better ſignify the one than the other.

7. That Artificial Forms are alſo natural. 7. Forms are commonly diſtinguiſhed into *Natural* and *Artificial*: They call thoſe *Natural*, which belong to the Subject without the Aſſiſtance of Men; Thus a Portion of Matter receives the Form of Marble in the Bowels of the Earth. *Artificial Forms* are thoſe that proceed from Art; thus the Form of a Clock is called *Artificial*, becauſe it is owing to the Labour of the Clock-maker. I agree, that if the Name had been given with regard only to the Cauſes by which they were produced, it would have been reaſonable to call the one *Natural*, and the other *Artificial*; but ſince it is inferred from thence, that the *Natural Forms* are different from the *Artificial Forms*, and that they act from internal Principles, which are very different from thoſe of *Artificial Forms*; there lies the Miſtake. For *Artificial Forms* are as natural as the *Natural Forms* themſelves, becauſe they proceed from Cauſes purely natural; and Art, as was ſaid before, does nothing elſe but apply active Things to paſſive Ones.

8. It

8. It is much more reaſonable to divide Forms into *Simple* and *Compound*. *Simple* Forms are thoſe of ſimple Beings, that is, of Beings that are capable of but a few Properties; and *compound* Forms are thoſe of compound Beings, that is, Beings that are capable of a great many Properties. For Inſtance, the Form of a hard Body, whatever that Form may be, is a *ſimple* Form compared with the Form of Wood, which, with reſpect to the former, may be ſaid to be *compounded*; becauſe a hard Body, as *hard*, is not capable of ſo many Properties as Wood.

8. The Diviſion of Forms into ſimple and compound.

9. This Obſervation is more remarkable than one would imagine. For it is evident, that *ſimple* Things may be known, when we don't at all know thoſe that are compounded of them: Whereas we cannot know thoſe that are *compounded*, but we muſt have a diſtinct Knowledge of thoſe Things which go towards their Compoſition. Wherefore in order to underſtand particularly the Forms of Bodies, it is neceſſary that we firſt begin with thoſe that are *ſimple*, and afterwards come to thoſe that are *compounded*.

9. That ſimple Forms ought to be underſtood firſt.

CHAP. XIX.

Of Elements according to the Opinion of the Antients.

IF we once have a clear Notion of what Philoſophers mean by the Word *Element*, we cannot doubt, but that the Forms of Elements are the moſt ſimple of all. It is to be obſerv'd therefore, that the principal Deſign of Philoſophers is to explain how every Thing is generated, in ſuch a manner as to let us know the different States through which ſuch Things paſs from their firſt Principles till they are entirely compleat, and in that perfect State in which we ſee them. And in order to this, ſince they find by Experience, that every Thing is not made indifferently out of another, and that Stones, for Inſtance, and Marble are not proper to be converted into Fleſh, neither will they ſerve to nouriſh it and make it grow; ſo they judge by proportion, that all ſorts of Bodies are not compounded of Principles alone, connected together in the moſt ſimple manner poſſible; but only ſome very ſimple Things

1. What Philoſophers mean by Elements.

Things, of the Mixture of which all other Things are afterwards compofed. Thefe very fimple Things, whatever they be, which thus arife from the firft *Determination* and Connexion of Principles, are what Philofophers call *Elements* : So that *Elements* differ from *Principles* in this, that a *Principle*, fuch as Matter, for Example, is, as it were, an *incompleat and undetermined Thing*, whereas an *Element*, is a *compleat and determined Thing*.

2. That there ought to be more Elements than one, and what the Opinion of the Antients was concerning Elements.

2. This being explained, there muft, without doubt, be *more than one Element*, otherwife there would be but one uniform Simplicity in Nature, and no compounded Things. But Philofophers have not agreed what is meant by *Element*; the Reafon of which is, becaufe they have not fo much inquired into *the Nature of Things themfelves* as into *the Senfations which they are apt to raife in us*. Thus fome Philofophers who confidered the Senfe of *Seeing* only, have afferted that *Light* and *Dark, Tranfparent* and *Opacous* were the Elements of Things. And others, who referred every Thing to *Feeling*, have pretended that *Hard* and *Liquid*, or *Hot* and *Cold* were the *Elements*.

3. How Ariftotle made Four Elements.

3. *Ariftotle* may be placed amongft the Number of thefe laft, though he went in a Way fomewhat different from theirs. He confidered firft, the principal Qualities that come under the Senfe of *Feeling*, fuch as *Heat, Cold, Drynefs* or *Hardnefs*, and *Moiftnefs* or *Liquidnefs* : And after he had obferved that two of thefe Qualities might meet in the fame Subject; and that the Four might be coupled four different Ways, he compofed four Elements ; of which the Firft is *Cold* and *Dry*, the Second is *Cold* and *Moift*, the Third, *Hot* and *Moift*, and the Fourth, *Hot* and *Dry*.

4. What Names he gave to them.

4. Then, in order to give Names to them, he examined what thofe Things in Nature were, in which one Element feemed to prevail, or in which its Qualities were moft fenfible. Thus, imagining the *Earth* to be both the coldeft and drieft Thing in the World, he called his *Firft Element, Earth*. So likewife, becaufe he thought that Water was the coldeft and moifteft Thing, he called his *Second Element Water*. Further, imagining alfo, that there is nothing more moift and hot than Air, he called his *Third Element, Air* ; And laftly, not doubting, but that Fire is the hotteft and dryeft Thing in the World, he called his *Fourth Element, Fire*.

5. *Ari-*

5. *Aristotle's* making uſe of Names which were before uſed to ſignify other Things, hath given occaſion to many, who did not rightly apprehend his Meaning, weakly to believe, that *This Earth which we inhabit*, *This Water which we drink*, *This Air which we breathe*, and *This Fire which we kindle*, are the *Four Elements*. But this will appear a very groſs Miſtake, to any one who conſiders, that the Name *Element* is given only to the *moſt ſimple Body*, whereas the four now mentioned are the moſt compounded of any we know.

5. That theſe have been miſunderſtood by ſome.

6. But if we ſuppoſe the *Elements* of *Ariſtotle* to be as ſimple as he makes them, and if we compare them with thoſe which other Philoſophers have attempted to introduce; we do not find any Advantage they have, why we ſhould prefer them above others; becauſe in this Matter we have no more reaſon to conſider the Qualities of *Feeling*, than thoſe of *Seeing*, or any other Senſe. But neither the one nor the other ought to be allowed, and that for theſe two Reaſons, which ſeem to me very ſtrong. The Firſt is, That in order to eſtabliſh *Elements* throughly, it ought to be upon the *Determinations* which may happen to Matter abſolutely and in it ſelf, and not upon the *Relations* which the different Forms of which it is capable may have to our Faculties to raiſe Senſation. The Second is, that all theſe pretended Elements being determined by ſenſible Qualities, of which we have no clear Notion; it is impoſſible, but that there muſt remain ſome Obſcurity, into which no Philoſopher can ſo far penetrate as to be able to ſee what will ariſe from their Mixture; in the ſame manner as a Phyſician cannot tell what is the Vertue of a Medicine compoſed of many ſimple ones, of which he has only a confuſed Knowledge.

6. That the Elements eſtabliſhed by Ariſtotle *and others, ought not to be received.*

CHAP.

CHAP. XX.

Of the Elements of the Chymists.

1\. *The Method of the Chymists, in finding out of Elements.*

I Cannot tell whether these or such like Reasons, induced the *Chymists* to reject those Elements which the Antients would have introduced; thus much is certain, that they had proposed others very different. And in order to establish them; as they profess an Art which consists principally in using Fire after different manners, to separate as much as is possible, the different Parts of which different Bodies are composed, they have pretended, that this Resolution is the only Way to find out what are the true Elements which Nature makes use of in the Composition of Bodies; as the taking a Machine to Pieces, is the only way to find out what it is composed of.

2\. *What the Mercury of the Chymists is.*

2\. Thus, in working upon certain Bodies, upon Wine, suppose, they put a large Quantity of it into an Alembick, and by means of Fire, make some of its Parts exhale, which being then condensed by the Cold, fall down into another Vessel in the Form of a strong, subtil, and penetrating Liquor, to which they are pleased to give the Name of *Mercury*, *Spirit*, or *Aqua-vitæ*.

3\. *What it is that they call Phlegm and Sulphur.*

3\. After this, continuing the Alembick upon the Fire, they make it distill a Liquor which has no Taste, and this they call *Phlegm*; and so they go on till there remains nothing in the Alembick, but a *glutinous Substance* like Honey. Then they put this glutinous Substance into a Retort, and with Fire they make it again distill a *Phlegm* like the former, and then an acid Liquor which they call Mercury also; and after that, another Liquor not quite so fluid, somewhat like Oil, and which is inflammable like it, to which they give the Name, *Sulphur*.

4\. *What it is that they call Caput Mortuum, and Salt.*

4\. Lastly, They take that which remains in the Retort, and which presently grows dry, and burn it, and put the Ashes into an Earthen Pot or Pan, with a certain Quantity of Water, which in a short time becomes Salt, then straining it off clear into another Vessel, there remains in the Pot a kind of dusty insipid Earth, which they call *Caput mortuum* or *Terra damnata*; then with a gentle Fire, they make the clear Water which is in the other Vessel to evaporate intirely, and after that, there remains at the

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Bottom of the Veſſel, a hard brittle Body which is very like Salt, and therefore they call it *Salt*.

5. Hence they conclude, that theſe five Subſtances, *viz.* *Mercury*, *Phlegm*, *Sulphur*, *Salt* and *Caput mortuum*, are the Elements of Wine: And becauſe whatever they can extract out of any other Subject reſembles one or other of theſe, therefore they conclude in general, that theſe Things, are the only and the true *Elements* of all the mixed Bodies which are in the World, and that all the Variety that we ſee is owing to the different Mixture of theſe.

5. That Mercury, Phlegm, Sulphur, Salt, and Caput mortuum, *are the Elements of the Chymiſts.*

6. I ſhould think it a great Piece of Injuſtice not to give the Chymiſts that Commendation which is due to their Induſtry and laborious Application. Without doubt the whole World, and the Philoſophers particularly, are very much obliged to them for the Pains they have taken, and which they continue to take, to make a great Number of Experiments, whereby they come to the Knowledge of diverſe Properties of many different Things. This gives them opportunity to find out and diſcover the Nature of Things, and at the ſame time, ſerves for a Rule to try the Truth of their Principles by, and to juſtify their Reaſoning and the Conſequences which they draw from thence. However I think their manner of treating of Philoſophy is not ſatisfactory, nor their *Elements* ſuch as ought to be allowed.

6. How Chymiſtry may be uſeful to Philoſophers.

7. *Though* the exceſſive Commendations which they give themſelves, and with which their Books are filled, as if they were the only Philoſophers, and the Secrets of Nature depoſited in their Hands alone; and *though* the large Promiſes they make, which for the moſt are falſe and vain, have rendred them almoſt univerſally contemptible to the World; and the obſcure Terms, and almoſt perpetual Equivocations which they uſe, have made them ridiculous alſo to a great many: *Yet* I do not depart from their Opinions upon this Account. For as to theſe exceſſive Commendations, and vain Promiſes, they are only perſonal Faults which any one may eaſily lay aſide, and which ſome Chymiſts of my Acquaintance are entirely free from; who far from being vain and proud like others, are on the contrary, ſo modeſt, that if they had nothing elſe to recommend them, they ought upon this Account to be placed in the Rank of Gentlemen. And as to the Obſcurity of their Terms, ſome of which are authorized by Cuſtom, that is eaſily diſperſed, if we give but our ſelves the Trouble to explain them.

7. The Errour of the Chymiſts.

8. That

8. That they cannot get together all the Parts of a mixed Body; and those which they do get together are altered.

8. That which makes me not to approve of the Method of the Chymists, is, first, because it is defective; for it is certain, that let them take never so much Pains, they can only get together the sensible Parts of which a Body is composed: For as to those which resemble that subtil Matter, the Existence of which, we demonstrated above, and which go to the Composition of a great many Things, these escape all their Pains. But further, that which they give the Name of Principle to, cannot but be very much altered, and very different from what it was in the Mixture: For it is impossible, but that the different Parts which they Extract, when they are put in Agitation by the Fire, and dashed one against another, must be changed both in their Figure and in their Nature. And this is confirmed by Experience, for if all the Parts into which the Mixture is resolved, be mixed together again, the Result will not be at all like the former Mixture.

9. That, allowing of their Opinion, there ought to be more than five Elements.

9. To this may be added, that the Chymists deceive themselves, in saying, that there are but five Elements: For allowing of their Method, and the Manner upon which it is founded, we must say, that there is a great Number, yea so great, that it is impossible to know them all. Thus there are a great many Sorts of *Mercury*, *Sulphur*, *Salt*, &c. But to mention *Salt* only; we find almost as many different Salts, as there are different Mixtures. For Example, That which is extracted out of an Ash-tree, is Caustick, that is, will corrode and burn the Flesh, if applied to it; but that which is extracted from an Oak will not do so.

10. That they have but a confused Notion of their own Elements.

10. But that which shocks me most in the Reasoning of the *Chymists*, is the Confusion that they are unwilling to get out of, and the Aversion they have to clear and distinct Knowledge, which it is so natural to desire. For Instance, if we ask them what they mean by *Sulphur*, they will answer indeed, that it is *a fat inflammable Substance*; but if we go on to ask what this fat inflammable Substance is, which they call Sulphur, and in what this Property of being Inflammable consists, they will not only not give us any further Answer, which indeed is no great Matter, because they have none to give; but they will be offended at our Curiosity, and that we should have any Desire to be satisfied herein: So that their Science extends no further than to give Names to things whose Natures they understand not, and consequently from the Mixture of which, it is impossible to foresee what will arise, which is

is one of the principal Conditions which we require in Elements.

11. Perhaps it will be ſaid here in favour of the Elements of the *Chymiſts*, and in favour of thoſe of the *Ariſtotelians*, that though we do not know diſtinctly what they are in themſelves, yet we know at leaſt what they are capable of, that is, the Senſations they raiſe in us, or the Convenience or Inconvenience we receive from them, which they think ſufficient to determine what the Effect of their Mixture will be. For, ſay they, we may lay down two general Rules hereupon; Firſt, *That if two things ſeparately, are capable of producing the ſame Effect, they will alſo be capable of producing it when they are mixed together.* Secondly, *That if Two things ſeparately, are capable of producing two contrary Effects, when they are compounded together, they will produce ſome middle Thing between theſe two Effects.* And theſe cannot be denied to be of good Uſe. *11. The pretended Uſe of the Elements of the Chymiſts and of the Antients.*

12. Though theſe Rules are for the moſt part found to be true, yet it will be very wrong to truſt too much to them; and I doubt not but the Chymiſts themſelves will diſown them; for they know very well, that he who exactly follows them, will many times form a Judgement contrary to Experience. *12. This pretended Uſe, may be the Occaſion of our making many falſe Judgements.*

13. For inſtance, if we follow theſe two Rules ſtrictly, we muſt affirm, that two Bodies which ſeparately are *cold*, ought together to make *one cold Body*. *13. The firſt Inſtance.*

14. We muſt affirm, that two *liquid Bodies* will compoſe *one liquid Body*. *14. II Inſtance.*

15. That two *tranſparent Liquors* will compoſe *one tranſparent Liquor*. *15. III Inſtance.*

16. That two *red Liquors* mixed together, will make *one red Liquor*. *16. IV Inſtance.*

17. That a Body of a *Yellowiſh Colour*, mixed with a Body of a *Green Colour*, ought to compoſe a *Yellowiſh Green*. *17. V Inſtance.*

18. That two things which may be ſeparately taken without any danger, may alſo be taken together without any. *18. VI Inſtance.*

19. However, we know that every one of theſe are contradicted by the following Experiments. For Example, cold *Lime*, having cold *Water* ſprinkled upon it, grows ſo hot, as to be ready to burn. Further, If *Oil of Vitriol* and *Oil of Tartar*, each of which are cold, be mixed together, we ſhall perceive a ſudden Ebullition, and at the ſame time a very ſenſible Heat. *19. The firſt Experiment of the contrary.*

20. If

20. II. *Experiment.* 20. If *Spirit of Wine* and *Spirit of Urine*, each of which are very fluid, be mixed together, they will, in a Moment almoſt, unite into a Body not at all fluid, but pretty hard.

21. III. *Experiment.* 21. If about an Ounce of *Litharge of Silver* be put into a Pint of *diſtilled Vinegar*, and boiled half a Quarter of an Hour, and if a Piece of *unſlacked Lime* be ſteeped Four and twenty Hours in a ſufficient Quantity of Water (it muſt be in an Earthen Pot varniſhed, new and clean;) and afterwards each of theſe Liquors be ſtrained, they will be very tranſparent; but when they are mixed, they will become opacous and of a very brown Colour.

22. *Of Sympathetick Ink.* 22. In the Uſe of theſe two Liquors conſiſts the whole Secret of the Ink, which they call *Sympathetick Ink.* They write that which they would not have ſeen, with the firſt Water, and the Writing diſappears the Moment that it is dry: Then, he who receives the Letter, wipes over the Paper with a Sponge ever ſo little moiſtned with the other Water, and the Writing begins to appear of a reddiſh Colour, tending to a Black. If theſe Waters are freſh made, and Care be taken to cover the Pot in which the unſlacked Lime is infuſed, the Sponge that is moiſten'd need not touch the Writing, in order to make it appear; it is ſufficient, if it paſs by it at a little diſtance: Nay I have often ſeen the Lime-Water ſo ſtrong, that when the Letter written with the firſt Water was laid upon a Table, and covered with a Quire of Paper, the upper Leaf of which only was moiſtned with the Second Water, the Writing grew black.

23. IV. *Experiment.* 23. If a Piece of *Braſil Wood* be boiled in Water over the Fire, we ſhall preſently have a Liquor pretty red; which if it be afterwards poured into a Glaſs in which there is ever ſo little Vinegar, this Colour will be changed into an Amber-Colour, and that ſo quick, that the firſt Colour will diſappear entirely, as ſoon as the Water touches the Bottom of the Glaſs.

24. V. *Experiment.* 24. It is certain, that *Nut-Galls* are of a Yellowiſh Colour, and that when they are reduced to Powder, there is no more Blackneſs in them, than in the Copperas, which is green; and yet if theſe two be infuſed in common Water for a few Days, or if you would have it quicker, if the Water be boiled an Hour or two over the Fire, they will be of one black Colour, and not differ from Ink but only in this, that they want the Gum Arabick.

25. Phy-

25. Phyſicians order ſometimes a few Drops of *Spirit of Nitre* or of *Oil of Vitriol* to be taken in Broth or ſome other Liquor, and theſe two Things taken ſeparately and in proper Caſes, are good Remedies, but if they be taken together, they are Poiſon. Now this Experiment, together with the foregoing ones, and many others that might have been added, do ſo evidently ſhow the Uncertainty of the two forementioned Rules, and conſequently the little Uſe of the *Elements of the Antients* and *of the Chymiſts*, that there is no need of adding any Thing more: That which now remains to be done, is to endeavour to diſcover what are *the true Elements of natural Things*. *25. VI. Experiment.*

CHAP. XXI.

Of the Elements of Natural Things.

THAT we may act here with all poſſible Caution, and eſtabliſh the number of Elements, upon the Conſideration of Things as they are in themſelves, without any regard to the Manner of their affecting us; we obſerve, that the firſt Thing that we can conceive to happen to Matter, is, that it may be divided into a great Number of Parts, all which are of a certain Figure. This Conſideration is of great Importance; for if we attend ever ſo little to it, we ſhall be ſurprized at ſome Perſons, who are ready to laugh, when we obſerve to them, that the Parts of Matter are of a certain Figure, and yet can ſeriouſly hearken to thoſe who tell them of occult Qualities, which they cannot at all comprehend *1. That we cannot be miſtaken in aſcribing Figures to the Parts of Matter.*

2. We obſerve further, that beſides thoſe groſs Bodies, ſuch as we can take notice of, with which we are ſurrounded; there are an infinite Number of others very ſmall, which eſcape our Sight, and which were not at all known to the Antients. Though even amongſt theſe, if we ſtrictly examine them, ſome may be made appear to us, ſuch as the *little Eels*, which ſpring up almoſt in a Moment, *in the beſt ſort of Vinegar ſet in the warm Sun*; but it is certain, we had not known of theſe ſmall Creatures to this very Day, were it not for the happy Invention of the Microſcope, in this Age. Thus, for Example, *Specks of Mould* upon the Covers of Books, have been long ob- *2. That there are a Multitude of very ſmall Bodies.*

 ſerved,

ſerved, and alſo, that a *Mite*, which is much leſs than a Grain of Sand, is an Animal, becauſe we can ſee it move along; but it is ſince the Invention of Microſcopes that we can with pleaſure ſee not only that they are ſo, but that every *Speck of Mould* is a little Garden covered with Plants, every one of which has its *Stalk*, *Leaves*, *Buds* and *Flowers*; and that a *Mite* has *its Back covered with Scales, that it has three Feet on each Side, and two black Spots in the Head*, which we ſuppoſe to be *Eyes*, becauſe if the Point of a Needle be put in its way, it will turn aſide.

3. That theſe Bodies conſiſt of Parts ſtill ſmaller. 3. Since ſuch ſmall Bodies are diſcovered and ſeen by the Microſcope, we may reaſonably judge that there are Parts incomparably leſs yet, which eſcape all our Senſes, all the Induſtry of Man, and exceed even our Imagination it ſelf. And that this may be clear by one Example; Since a *Mite* walks along, it muſt have *Legs*, and theſe Legs muſt neceſſarily have *Joints*. In order to move the Joints, there muſt be *Muſcles*, *Nerves* and *Tendons*, and in theſe Nerves *Fibres*, ſuch as we ſee in thoſe of larger Animals, or at leaſt, ſomething equivalent to them: And if we would carry this Conſideration yet further, and ſpeak of the *Heart*, *Blood*, *Brain*, *and Animal Spirits*, we ſhall be quite at a Loſs, and forced to confeſs, that our Imagination is unable to comprehend or repreſent the extreme Smallneſs of the leaſt Parts of which a Mite is compoſed. I deſire that theſe Things may be well conſidered, and I have purpoſely urged them, to avoid the Impertinence of thoſe Perſons, who ridicule every Thing propoſed to them, which does not agree with their groſs Notions; and who make a Jeſt of it, when we mention that ſubtle Matter to them, whoſe quick Motion and Smallneſs makes a Paſſage for it, and finds it a Place every where.

4. That Elements ariſe from the firſt Diviſion that can be of Matter. 4. Having laid down theſe Obſervations, ſince we are aſſured, that the ſmalleſt Bodies in the World, as well as the larger, ariſe from the Mixture of Elements; and ſince it is certain, that a ſufficient Number of the ſmalleſt Parts, may compoſe as great a Body as we will; we muſt conclude, that there ought to be as many Elements, as there can be remarkable Differences in the inſenſible Parts of Matter upon their firſt Diviſion.

5. That we do not here ſpeak of the Diviſion that was made at the Creation of the World. 5. Now that my Mind may be the clearer underſtood, I muſt repeat the Advice which I before gave, *viz.* That I conſider Things in their mere natural State. And though I am very well aware, that the firſt Diviſion of Matter was made by God, and as he pleaſed, when he created the

the World; yet that is not the Divifion I am here fpeaking of, becaufe I believe the Creation to be a Myftery which I cannot fearch to the Bottom of. So that I fpeak of another Divifion, which may be made agreeably to the Notions we have, and of which all the Things in the World are the Confequences.

6. What that Divifion is which I fuppofe Elements to arife from.

6. Thus, confidering as far as I am able all Matter, I firft divide it in my Mind into an infinite Number of Parts very near equal, not troubling my felf what Figure they are of, becaufe, there may be a great many other Figures, befides Cubick which comes firft into every one's Thought, that may produce the fame Effect. After this, I fuppofe that God turns every one of thefe little Particles, in many different Manners, about their feveral Centers, in order that a true Divifion of them from each other may begin to be made.

7. That there muft neceffarily be three Elements.

7. This being fuppofed, it cannot be but that all thefe Particles of Matter muft be broken where-ever they are Angular, or are intangled with thofe that join to them; fo that thofe which were fuppofed before to be very fmall, muft become ftill fmaller and fmaller, till they are got into a Spherical Figure. Thus we have two Sorts of Matter determined, which we ought to account the two firft Elements. And of thefe two we here call that which confifts of the *very fine Duft* which comes off from thofe Particles, which are not quite fo fmall, when they are turned round, the *firft Element*. And thefe Particles thus made round, we call the *Second Element*. And becaufe it may be, that fome of the fmall Parts of Matter, either fingly or united together, may continue in *irregular and confufed Figures*, not fo proper for Motion, we take them for the *third Element*, and join them to the other two.

8. The Properties of Elements.

8. As to the chief Properties of thefe *three Elements*, it is to be obferved, that it is no Contradiction to fuppofe them to be changed from one Sort to another: Thus the Particles of the *Third Element* may fometimes be made round, and acquire the Form of the *Second*. And thofe of the *Second* and *Third* may be broken, and fo converted into the *Firft*. But none of thefe three *Elements* will better preferve their Form than the *Second*, becaufe it is more folid, and the Spherical Figure, which it is of, will allow it to move about it felf, without being intangled with the Particles about it. On the contrary, none are fo eafily changed as the *Firft*, becaufe its Particles moving very quick, and being very fubtle, they cannot refift the Shock of the Particles belonging to the other Elements, when they

meet with them, but are forced at all times to suit their Figures to those of the Places through which they pass, and where their Motion carries them.

9. The Properties of the First. 9. The *First Element* ought also to have more Motion than either of the other *Two*, for though all the three *Elements*, were at the Beginning equally moved by the First Mover, yet it must afterwards happen, that the *first Element* having oftentimes met with other Bodies which resisted it, and which it could not move, will be reflected back, without losing any of its own Motion; whereas the other *Elements* cannot meet this, but they will move it, and so increase its Motion by diminishing their own.

10. How the First Element acquires greater Velocity than the other Two. 10. And since the *First Element* is often forced to run into those little Intervals which are between the small Globes of the *Second Element*, it must necessarily be, that many of its Parts being compressed, will leave the Place where they are, and get forward; and so having a Motion compounded of their own Motion, and of that of the Parts which follow them and press upon them, they will acquire a greater Velocity than the Parts of the *Second Element* which force them on. In the same manner as the Air contained in a pair of Bellows goes out with much greater Velocity than the Sides of the Bellows approach each other, and which by their approaching, push it, and make it to go out.

11. Why we do not give proper Names to these Elements. 11. I would have it observed by the way, that I might, after the Example of *Aristotle*, give Names to the *three* forementioned *Elements*, from the Things which partake most of them: Thus, I might give the Name *Fire* to the *First Element*, *Air* to the *Second*, and *Earth* to the *Third*. But besides, that this would be to act contrary to Order, because I have not yet proved, that *Fire* is for the most part composed of the *First Element*, *Air* of the *Second*, and *Earth* of the *Third*; there is yet another Reason that ought to hinder me from doing it, and that is, that I should give Occasion for abusing them, and for having them understood in another Sense than what I intend they should be.

12. That these three Elements are not imaginary. 12. Perhaps it will be here said, that Matter was not divided in the Beginning as I have supposed; But tho' I agree it may be so, this makes nothing against me; for it signifies very little how Matter was divided at the Beginning; and in what manner soever it was divided, there is no doubt but it is now divided into those three Sorts of Matter which I have described; it being certain, that they necessarily

sarily follow from the Motion and the Division of the Parts of Matter which Experience obliges us to acknowledge in the Universe. So that the *Three Elements* which I have established, ought not to be looked upon as imaginary Things; but on the contrary, as they are very easy to conceive, and we see a necessity of their Existence, 1 we cannot reasonably lay aside the Use of them, in explaining Effects purely Material.

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1. *We cannot reasonably lay aside*) These *three Elements* are to be looked upon as fictitious and imaginary, because they depend upon a *Plenum* every where, which we have before rejected. But concerning the *true Elements* of Nature, the illustrious *Newton* thus explains himself.

It seems probable to me, that God in the Beginning formed Matter in solid, massy, hard, impenetrable, moveable Particles, of such Sizes and Figures, and with such other Properties, and in such Proportion to Space, as most conduced to the End for which he formed them; and that these Primitive Particles being Solid, are incomparably harder than any porous Bodies compounded of them; even so very hard, as never to wear or break in Pieces: No ordinary Power being able to divide what God himself made one in the first Creation. While the Particles continue entire, they may compose Bodies of one and the same Nature and Texture in all Ages: But should they wear away or break in Pieces, the Nature of Things depending on them, would be changed. Water and Earth composed of old worn Particles and Fragments of Particles, would not be of the same Nature and Texture now, with Water and Earth composed of entire Particles in the Beginning. And therefore that Nature may be lasting, the Changes of corporeal Things are to be placed only in the various Separations and new Associations and Motions of these permanent Particles; compound Bodies being apt to break, not in the midst of solid Particles, but where those Particles are laid together, and only touch in a few Points. Opticks pag. 375.

Further, nothing can be more absurd than to imagine, that all these surprizing Things in the Universe, arise and were formed out of those three Elements of *Cartes*, and by the Motion impressed upon them in the Beginning, without any Interposition afterwards, either of God himself, or any other intelligent Cause. For according to that Hypothesis, the Followers of *Cartes* have not so much as dared to attempt explaining how all Kind of *Plants* and *Animal Bodies* (which are the principal and most excellent Part of this Universe) were at first made, and by what Laws of Motion they were framed. How much better does the foremention'd admirable Person express himself.

Now all material Things seem to have been composed of the hard and solid Particles abovemention'd, variously associated in the first Creation by the Council of an intelligent Agent. For it became him who created them to set them in order. And if he did so, 'tis unphilosophical to seek for any other Origin of the World, or to pretend that it might arise out of a Chaos by the mere Laws of Nature; though being once formed, it may continue by those Laws for many Ages. For while Comets move in very excentrick Orbs in all Manner of Positions, blind Fate could never make all the Planets move one and the same way in Orbs concentrick, some inconsiderable Irregularities excepted, which may have risen from the mutual Actions of Comets and Planets upon one another, and will be apt to increase, 'till this System wants a Reformation. Such a wonderful Uniformity in the Planetary System must be allowed the Effect of Choice. And so must the Uniformity in the Bodies of Animals, they having generally a right and a left Side shaped alike, and on either Side of their Bodies, two Legs behind, and either two Arms, or two Legs, or two Wings before upon their Shoulders, and between their Shoulders a Neck running down into a Back-bone, and a Head upon it; And in the Head

CHAP. XXII.

Of the Form of a Hard and of a Liquid Body, or of Hardneſs and Liquidity.

1. *What is meant by hard and liquid Bodies.* BECAUSE it is by means of our Senſes, that we find out the principal Differences obſerved in Things; I think we cannot do better, than to conſult them one after another, to find out in what Order the Forms of natural Bodies ought to be treated, beginning with thoſe that diſcover to us the feweſt Properties of their Objects. And ſince the Senſe of *Feeling* is the groſſeſt of all, and that which takes up the leaſt Compaſs of our Views, I will begin my Inquiry with that. Now when we make uſe of the Senſe of Feeling, to diſcover what Sort of Bodies they are which ſurround us, we obſerve that there are ſome which reſiſt the Motion of our Hands, and will not be divided without great Difficulty; on the contrary, there are others which do not reſiſt them at all, but are very eaſily divided all ways; the firſt of theſe we call *hard Bodies*, and the other *liquid Bodies*; and we ſay, that a Body is ſo much the harder, as there is greater Difficulty in dividing it, and another ſo much the ſofter, as it reſiſts leſs, and is divided with greater eaſe. And thoſe Bodies which are of a middle Sort, betwixt hard and liquid, and which reſiſt our Feeling, or the Motion of our Hand but a little, theſe we call *ſoft*.

Head two Ears, two Eyes, a Noſe, a Mouth, and a Tongue, alike ſituated. Alſo the firſt Contrivance of thoſe very artificial Parts of Animals, the Eyes, Ears, Brain, Muſcles, Heart, Lungs, Midriff, Glands, Larynx, Hands, Wings, ſwimming Bladders, natural Spectacles, and other Organs of Senſe and Motion; and the Inſtinct of Brutes and Inſects can be the Effect of nothing elſe than the Wiſdom and Skill of a powerful everlaſting Agent, who being in all Places, is more able by his Will to move the Bodies within his boundleſs uniform Senſorium, *and thereby to form and reform the Parts of the Univerſe, than we are by our Will to move the Parts of our own Bodies. And yet we are not to conſider the World as the Body of God, or the ſeveral Parts thereof as Parts of God. He is an uniform Being, void of Organs, Members or Parts, and they are his Creatures ſubordinate to him, and ſubſervient to his Will. And he is no more the Soul of them, than the Soul of a Man is the Soul of the Species of Things carried through the Organs of Senſe, into the place of his Senſation, where it perceives them by means of its immediate preſence without the Intervention of any Third Thing. The Organs of Senſe are not for enabling the Soul to perceive the Species of Things in its* Senſorium, *but only for conveying them thither; and God has no need of ſuch Organs, he being every where preſent to the Things themſelves.* Ibid. p. 378.

2. We

2. We observe also that a Body, which resists the Touch and is with Difficulty divided, keeps it self also within its proper Limits, and preserves its Figure, without wanting a Vessel to contain it; and on the other hand, that a Body which does not resist the Touch, does not contain it self within its Limits, but runs and spreads about, if it be not put into some Vessel. Wherefore *Aristotle* having given the Name of *Dry* to a Body which is contained within its proper Limits, and that of *Moist*, to a Body which does not do so, but wants to be contained within the Limits of another; it follows that the *hard* Body we are speaking of is the same as what *Aristotle* called *Dry*, or at least a Species of it; and also that the *Liquid* is the same with the *Moist*, or at least a Species of it.

2. That hard and liquid Bodies are the same kind of Bodies as the dry and moist Bodies of the Ancients.

3. As *Aristotle* has not explained what *Dryness* and *Moistness* consist in, so neither has he explained the Nature of a *hard* and a *liquid* Body. But most of his Followers contend, that a Body is *hard*, because it comprehends a great deal of Matter in a little Compass, and that a Body is *liquid*, because it contains but a little Matter in a great Compass; so that they make *Hardness* to consist in Condensation, and *Liquidness* in Rarefaction.

3. In what the Followers of Aristotle, *make Hardness and Liquidness to consist.*

4. It is to be observed, that they would be understood to speak here of a Rarefaction, without the Addition of any Matter at all, not so much as of foreign Matter; and of a Condensation which does not in the least suppose any Sort of Matter to come out of the Pores of the condensed Body; which Things are directly opposite to what has been before established; wherefore it cannot be thought strange, if we do not agree together as to the Nature of hard and liquid Bodies.

4. That their Opinion goes upon a false Supposition.

5. But if Rarefaction and Condensation were made as they pretend, yet it were easy to prove that they are mistaken in their Notion of Hardness and Liquidness: For as the producing one Piece of white Marble, is sufficient to show, that the Nature of Marble does not consist in Blackness, so it shall suffice to bring one Instance of a Body which dilates it self when it grows hard, in order to show that Hardness does not consist in Condensation: Thus we see that Water is dilated, when it is turned into Ice, for the Vessels which contained it, and just

5. A Confutation of the Opinion of the Aristotelians, *and the Reason why Vessels full of Water are broken by the Frost.*

held it, cannot then contain it, [1] but are many times broken.

6. A Mistake of the Aristotelians, *as to the Reason why Vessels are broken by the Frost.*

6. I know very well, that it will here be answered as usual, that the Vessels would not be broken, but for fear of a *Vacuum:* That is, because their Sides approach one another, that there may not be any Space left between their Concave Superficies and the Convex Superficies of the Water which is condensed. But if this were true, it would follow, that all the Glass Tubes which we used in the forementioned Experiments, ought also to be broken, when no Air got into the Place out of which the Quicksilver came, which did not come to pass, as I have oftentimes tried.

7. Another Proof that Ice is not condensed Water, and why it swims upon the Water.

7. Add to this, that if Ice were only condensed Water; to make for Instance, a Cubick Foot of Ice, there must be more than a Cubick Foot of Water, and consequently a Piece of Ice would weigh more than a Quantity of Water of the same Dimensions. From whence it follows, according to what has been before demonstrated, that Ice ought to sink to the Bottom of the Water, and not swim at the Top, as we find it does.

8. An ocular Demonstration of the same Thing.

8. But for the full Conviction of those who seem to defy all Arguments, and trust only to what they see, let them but take a Glass of the Shape of an inverted Cone or Pyramid, and after having filled it quite full of Water, expose it to a great Frost, that the Water may become Ice; then if the Glass holds but half a Pint, we shall see the Ice rise up about the sixth Part of an Inch above the Mouth of the Glass, which is [2] a Dilatation sensible enough not to doubt of the Fact.

9. What the Nature of a hard Body consists in.

9. This then is a certain Truth, that every Body which becomes hard, is not condensed; and therefore Hardness does not consist in Condensation, nor consequently does Liquidness consist in Rarefaction; for as Water is dilated by freezing, so is Ice condensed by thawing. Having thus sufficiently confuted an Opinion which has been so long received, and not thinking it worth while, to show how little Foundation there is for other Opinions which have been received only by a few, I come now to establish my own. And first I examine the Appearances of

1. So great is the Force of freezing Water, that not only Bowls and Glass Cups, but also large Vessels of Brass and Silver are broken by it. See *Experim. Accad. del Cim.* p. 72.

2. *A Dilatation sensible enough*) Yet it must not be dissembled, that something may possibly be here ascribed to the Contraction of the Glass. See *the Notes on Chap.* 23. *Art.* 36.

a *hard*

a *hard* and of a *liquid* Body, and find, that the one contains it self within its proper Bounds, and the other does not: And because to be contained within its proper Bounds, is the same Thing as not to be moved; I conclude, that *to be hard,* is *to be composed of Particles which are* 1 *so at rest among themselves, that their Connexion and Order, is not disturbed by any Matter that moves between them.*

1. *So at rest among themselves*) Though all hard Bodies have Parts in some measure at rest, and many liquid Bodies (*viz.* such as are made liquid by Heat) are manifestly very much agitated; yet because something more than the bare Rest of the Parts seems requisite to constitute Hardness; (for a Heap of very small Sand, whose Particles are all at rest, is not a hard Body;) and because Motion does not seem always necessary to constitute a liquid Body, (for some liquid Bodies are very cold;) I think it therefore worth while to add something here, to explain this Matter more fully.

First then, let us hear what the famous *Newton* says, concerning that Force by which the primary and naturally indivisible Corpuscles of which the Particles of all Bodies are composed, are connected and cohere together.

The Parts of all homogeneal hard Bodies which fully touch one another, stick together very strongly. And for explaining how this may be, some have invented hooked Atoms, *which is begging the Question; and others tell us, that Bodies are glued together by* Rest, *that is, by an occult Quality or rather by* Nothing; *and others that they stick together by* conspiring Motions: *I had rather infer from their Cohæsion, that their Particles* attract *one another by some Force which in immediate Contract is exceeding strong, at small distances performs the Chymical Operations abovemention'd, and reaches not far from the Particles with any sensible effect-- Now if compound Bodies are so very hard, as we find some of them to be, and yet are very porous, and consist of Parts which are only laid together, the simple Particles which are void of Pores, and were never yet divided, must be much harder. For such hard Particles being heaped up together, can scarce touch one another in more than a few Points, and therefore must be separable by much less Force than is requisite to break a solid Particle, whose Parts touch in all the Space between them, without any Pores or Interstices to weaken their Cohæsion. And how such very hard Particles which are only laid together, and touch only in a few Points, can stick together, and that so firmly as they do, without the Assistance of something which causes them to be* attracted *or pressed towards one another, is very difficult to conceive.---Now the smallest Particles of Matter, may cohere by the strongest Attractions, and compose bigger Particles of weaker Virtue; and many of these may cohere, and compose bigger Particles whose Virtue is still weaker: And so on,* &c. Opticks Ibid. p. 364. 370.

It is evident therefore, that the Particles of which the original and smallest Parts of Matter are composed, stick together and are united, not by *Rest* (which is really *nothing* at all) but by mutual *Attraction.* (See the Notes above on *Chap.* xi. *Art.* 15.) And it is manifest, that all Bodies, *fluid* and *solid* are equally compounded of such sort of Particles entirely solid and *perfectly hard.* But that which is next to be enquired into, is, what the Figure and Composition of the larger Particles must be, in order that the Bodies composed of them, may be *hard* or *liquid.*

Secondly therefore. That Body, whose Particles are so fitted to each other, as to touch one another in *large Superficies's,* will, by the very strong mutual Attraction of its Parts, be *a very hard Body;* and according as those Parts afterwards either *touch* one another *only,* or are moreover intangled with each other, will the Body be more or less *brittle,* and capable of being made *liquid* by Heat, with more or less difficulty: *As Ice, Wax, Glass, Metals, Bones, Wood,* &c.

Thirdly,

them. Whence it follows, that a Body is so much the harder, as it has more Parts which immediately touch each other without moving.

10. What the Nature of a liquid Body consists in. 10. On the other Hand; because, not to contain it self within its proper Bounds, is the same Thing as to move it self; and because we cannot conceive any more effectual Cause of that Motion which we see in a *liquid* Body, than the Motion of its insensible Parts; I therefore conclude, 2 that *Liquidness* consists in *the perpetual Agitation of the insensible Parts of the liquid Body.* Thus for Example, when a Glass full of Water set upon a Table is at rest, though we cannot perceive any sensible Agitation

Thirdly, That Body whose Particles touch one another in *less Superficies,* and therefore are not so *hard,* may yet be more *solid*; and therefore *Gold* is heavier than a *Diamond,* though *not so hard.*

Fourthly, That Body, whose Particles, when they are compressed, *approach* towards each other, but do not *slip under* one another, is an *elastick* Body, and returns to its Figure, by that Force which arises from the mutual Attraction of its Parts.

Fifthly, That Body, whose Particles *slip* under each other, is a *soft* Body, which yields to the Stroke of a Hammer.

Sixthly, That Body, whose Particles touch one another in *very small Superficies,* is a *crumbling* Body, as *Snow,* or such whose Parts may very easily be *separated*; as *too well polished Marbles,* which stick together in a *Vacuum,* but are pulled asunder by the least Shake.

Seventhly, If the Parts of a Body, either do *not touch* one another at all, or at least will *very easily slip,* and are of such a Bigness, as to be easily agitated by Heat; and the Heat be sufficient to agitate them, though perhaps it be much less than is required to keep Water from freezing; or if they be not agitated by Motion, but are only small, round, slippery, of such a Figure, and Bigness, as make them very easily agitated and give way; that is a fluid Body. And yet the Particles of such sort of Bodies which are *most fluid,* do in some measure cohere together; as is evident from hence, that *Quicksilver* very well cleared of all Air, will stand 60 or 70 Inches high in the Barometer (as was said before). And Water will rise in small Tubes open at both Ends in a *Vacuum.* And Drops of Liquors hanging upon a hard Body, and just ready to fall, will gather themselves into round Figures in a *Vacuum*: viz. by such a mutual Attraction of their Particles, as that by which the *polished Marbles* stick together. Further, These fluid Bodies, if they have Particles which can easily be intangled with one another, as *Oil* or such as may be made stiff by Cold, and fastned together, as if they had Wedges put between them, as *Water,* such Bodies easily grow hard. But if they have such sort of Particles, as can neither be intangled with each other, as *Air,* nor made stiff by Cold, as *Quicksilver,* then they cannot by any means be made to congeal.

Eighthly, If the Parts of a Body be very small, spherical, and exceeding dense, such a Body may also be *fluid,* and yet be much heavier, than harder Bodies, whose Particles are not so solid, but which touch one another in larger Superficies.

Ninthly, Those Bodies, whose Particles are agitated with a very quick Motion all ways, whatever the Figure of them be, will be liquid, as *Metals that are melted,* &c. But such Bodies grow hard, as soon as that violent Motion ceases.

Lastly, Those Bodies, some of whose Particles are intangled with each other, some of which touch one another in large Superficies, and some are loose, and will easily slip under each other, these are *flexile* as *Leather,* or very *pliant* as Twigs, *Glue,* *Pitch.* &c.

2. *That Liquidness consists)* See the Notes on the foregoing Artic.

tation in it, yet notwithſtanding, ſome of its Parts are in Motion downwards, and at the ſame time others of them are in Motion upwards, ſome of them move from the Right to the Left, and others from the Left to the Right; in a Word, there are ſome Parts of the Water which move in all manner of Determinations; whence it follows, that That Body is the moſt liquid, whoſe inſenſible Parts are the ſmalleſt, and the moſt agitated.

11. If what I have now ſaid of Liquidneſs be joined to what was before ſaid concerning Hardneſs, we ſhall eaſily conceive that a *ſoft* Body, which ſeems to be of a middle Nature betwixt a hard and a liquid Body, and to partake of them both, is therefore ſoft, becauſe it is compoſed of two Sorts of Parts, the one in ſome meaſure *at reſt*, and connected with each other, while the other are *in Motion*, and thereby cauſe ſome ſmall Agitation in the former. *11. What the Nature of a ſoft Body conſiſts in.*

12. Now that which confirms me in my Opinion concerning the Nature of *hard* and *liquid* Bodies, is, that the chief Properties of them are neceſſarily deduced from thence. And Firſt, Suppoſe the Nature of a hard Body to conſiſt in what I have ſaid, it follows from thence, that *it muſt be with difficulty divided*: For, for Inſtance, if I put my Finger to any of its Parts, I ought to feel the Reſiſtance, not only of thoſe Parts which I touch, but alſo of all thoſe Parts which are behind them; and many times it is much eaſier to move the whole hard Body, than to ſeparate one Part from it, becauſe the reſt of the Body has a ſtronger Connection with, and is more at reſt, with reſpect to this Part, than the neighbouring Bodies have with the whole Body. *12. Why a hard Body reſiſts the Touch.*

13. On the contrary, ſuppoſe the Nature of a liquid Body to conſiſt in what I have ſaid, it follows from thence, that a Liquid *muſt be very eaſily divided*. And indeed if I put my Finger to it any way, it meets with no Reſiſtance; for thoſe few inſenſible Parts which my Finger touch, being in Motion already, are very ready to quit their Place; neither are they ſupported, or hindred by the Reſiſtance of thoſe which are beyond, which are alſo in continual Motion, and therefore eaſily yield to them, and open a Paſſage for them all ways. *13. Why a liquid Body is eaſily divided.*

14. What I have advanced concerning the Nature of a hard and of a liquid Body, is ſtill further confirmed from hence, that all the Conſequences that can be drawn from it, help to explain ſome Experiment, which perhaps it would *14. Why many Bodies are preſerved uncorrupted, within the parts of a hard Body.*

would be impoſſible to explain without it. And firſt, if we conſider that ſome Bodies are eaſily altered, only by diſturbing the Order of their Parts, and that every Thing endeavours as much as it can to continue in that State in which it is, and conſequently that which is once at reſt, will never begin of it ſelf to move; it will not be difficult to find out a very eaſy way *to preſerve a hard Body a very long time*, viz. *by incloſing it in another hard Body*; whoſe Parts being at reſt among themſelves, can make no Impreſſion upon it, and are moreover a Guard upon it, againſt the Aſſault of any external Cauſes which might tend to corrupt it. And thus we ſee that Salt, Sugar, and Metals, are preſerved by being thus incloſed in hard Bodies.

15. Of the Vertue of Liquors to diſſolve certain Bodies.

15. On the other hand, it is eaſy to foreſee, that the contrary ought to happen, *if hard Bodies be put into Liquids*: For the Parts of Liquors being [1] in continual Agitation, they may eaſily ſo *ſhake* and *move* the Parts of hard Bodies, as to force them out of their Places, and carry them along with them. And thus we find it by Experience, in all hard Bodies that can be altered, as in Sugar and Salts, which are diſſipated and ſink to the Bottom of the Water almoſt in a Moment; inſomuch, that if we throw a Pound of Sugar into a great Tub of Water, it will intirely diſappear in a ſhort time; and the Parts of it, [2] will alſo be ſo diſſipated, and ſpread amongſt all the Drops of Water, that there will not be one of them but what is impregnated with it.

16. Why a Liquor does not entirely diſſolve certain Bodies.

16. And ſince hard Bodies may be compoſed of Parts of *different Bigneſſes*, as well as liquid Bodies, it is eaſy to conceive, that there may be ſuch a Liquor as *will cer-*

1. *In continual Agitation*) See the Notes upon Art. 9.

2. *Will alſo be diſſipated*) The illuſtrious *Newton* thus expreſſes himſelf upon this Subject in his Opticks, p. 362. *If a very ſmall Quantity of any Salt or Vitriol be diſſolved in a great Quantity of Water; the Particles of the Salt or Vitriol will not ſink to the Bottom, though they be heavier in Specie than the Water, but will evenly diffuſe themſelves into all the Water, ſo as to make it as ſaline at the Top as at the Bottom. And does not this imply, that the Parts of the Salt or Vitriol recede from one another, and endeavour to expand themſelves, and get as far aſunder, as the Quantity of Water in which they float, will allow? And does not this Endeavour imply, that they have a repulſive Force by which they fly from one another, or at leaſt, that they attract the Water* (See the Notes on Chap. xi) *more ſtrongly than they do one another? For all Things aſcend in Water, which are leſs attracted than Water by the gravitating Power of the Earth; ſo all the Particles of Salt which float in Water, and are leſs attracted than Water by any one Particle of Salt, muſt recede from that Particle, and give way to the more attracted Water.*

ry away with it only ſome certain Parts of a hard Body, and that others will not be diſplaced by it. Thus Water will only waſh off the fineſt Parts of Liquoriſh, and leave the groſſer ones at reſt with each other.

17. *Of the diſſolving Power of Aqua fortis.*

17. It may alſo ſo happen in *hard Bodies, that the Parts of them which are pretty near equal,* may yet be ſo *ſolid;* and on the contrary, *all the Parts of a certain Liquor* may be ſo *ſmall,* that the Parts of the hard Body will not be at all moved by them, as they would be by the *groſſer* Parts of another Liquor; which doubtleſs is the Reaſon why *common Water,* will not diſſolve *Silver,* and why *Aqua Fortis,* which the *Chymiſts* call *Spirit of Nitre;* [1] will eaſily diſſolve *it,* but is too weak to diſſolve Gold.

18. *Why Aqua regia does not diſſolve Silver.*

18. However, it is not only the *Groſsneſs of the Parts* of any Liquid, which renders it capable of ſeparating the Parts of a hard Body; the *Pores* which are between the Parts of a hard Body, do alſo contribute towards it: For they may be of ſuch a Figure, and alſo ſo ſmall, that the Parts of the Liquid cannot penetrate them; from whence we may conclude, that the Parts of the Salts of which *Aqua regia* is made, are put together in ſuch a manner, as to compoſe Bodies [2] too groſs to enter the Pores of Silver, and ſo only ſliding by them, they can neither go in, nor divide the Parts: Wherefore it is not to be wondred at, if this Water will not diſſolve *Silver,* though it diſſolves *Gold.*

19. It

1. *Will eaſily diſſolve it*) Concerning the diſſolving of Metals the ſame celebrated Perſon ſays thus. *When Aqua Fortis, or Spirit of Vitriol poured upon Filings of Iron, diſſolves the Filings with a great Heat and Ebullition, is not this Heat and Ebullition effected by a violent Motion of the Parts, and does not that Motion argue, that the acid Parts of the Liquor ruſh towards the Parts of the Metal with violence, and run forcibly into its Pores, till they get between its utmoſt Particles, and the main Maſs of the Metal, and ſurrounding thoſe Particles, looſen them from the main Maſs and ſet them at liberty to float off into the Water? And when the acid Particles, which alone would diſtil with an eaſy Heat, will not ſeparate from the Particles of the Metals, without a very violent Heat, does not this confirm the Attraction between them?* Opticks, p. 352. Now this ſame *Aqua fortis* which eaſily diſſolves *Iron* or *Silver,* will not diſſolve *Gold* at all; the Reaſon of which is, becauſe its Particles, which are more ſtrongly attracted by the Particles of *Iron* or *Silver* than by one another, are on the other hand more ſtrongly attracted by one another than by the Particles of Gold. The contrary to which we are to underſtand of that Force by which *Gold* is diſſolved in *Aqua regia.*

2. *Too groſs to enter*) *Mr.* Clerc *in his Phyſicks, Book II. Chap.* iv. *Sect.* 24. contends on the contrary, *that the Parts of* Aqua regia, *are ſharper and ſmaller than thoſe of* Aqua fortis, *and therefore can enter the very ſmall Pores of Gold only, and ſeparate its Parts, which like Wedges they drive from one another, whilſt the groſſer ones move about the Superficies of the Gold to no purpoſe, they not being able to diſſolve the continuity of it, becauſe they cannot en-*

ter

19. The Method of separating Gold from Silver. 19. It is from the Consideration of the different Properties of the several Sorts of *Aqua fortis*, that the Refiners of Gold have lately found out a way of separating *Gold* from *Silver* mixed with it: The whole Secret of which consists in putting the Mass composed of *Gold* and *Silver* into *Aqua fortis*, which will dissolve the *Silver* only; for then its Parts will be brought out by those of the Liquid, till the pure *Gold* will remain like Sand or Dregs at the Bottom of the Vessel; so that by inclining it gently, and pouring the *Aqua fortis* into another Vessel, it will carry the *Silver* along with it, and leave the *Gold* at the Bottom: After this, they separate the *Silver* from the *Aqua fortis* in the following manner; they put a Quantity of common Water to the *Aqua fortis*, to make it less corrosive, and then put in a Piece of Copper, against which the Particles of *Silver* brought out by the Liquid striking, they are stopped by it; in the same manner as Dust flying about a Room is stopped by the Hangings or any other Furniture which is soft, or as a Stone sticks, when it is cast into a Mortar. The *Gold* and the *Silver* being thus separated from one another in Dust, may each of them be melted in a Crucible, and then made distinct Masses of.

20. Why the Parts of many Bodies which are heavier than Water, do not sink in it. 20. It may here be asked, why the small Particles of Salts and Metals, swim thus in all the Parts of common Water or *Aqua fortis* indifferently, and whence it is, that they do not sink to the Bottom of the Vessels? For this

ter its Pores. And again, Sect. 28. He says, *That from the Mixture of many Salts, the Parts of the* Aqua regia *become smaller, and more fitted to enter the smallest Pores, and separate the smallest Parts: between which they are driven like Wedges, by the Motion of the Liquid in which they swim; but when they enter into wider Pores, they have no Effect; in the same manner as the Force of Wedges to separate Things joined together, is nothing unless they be driven into streight Fissures. Since therefore the Pores of Gold are the smallest of any Metal, they will admit the Particles of* Aqua regia *only, and the grosser Parts of* Aqua fortis *cannot enter into them. Now the same Parts of* Aqua regia *are too subtle to have Strength enough to remove the Sides of the Pores of other Metals; for they want the grosser Parts of* Aqua fortis *which fill and divide the larger Pores.* Thus far he; but what he says, he does not confirm by any Arguments or Reasons, unless it be this, that Silver seems to have larger Pores than Gold, because it is lighter; but from the known Properties of Silver, its hardness, smoothness, *&c.* we may with much greater Probability collect, that it consists of smaller Particles, and therefore has smaller Pores, though more of them; But that Gold on the contrary, consists of * larger Particles or Lumps, and so has larger Pores, but much fewer. And as to the Nature of the Liquids, I should think, that the Parts of the *Aqua regia*, would become not smaller, but larger by the Mixture of many Salts. But all this depends, as was said before, not so much upon the Bigness and Figure of the Pores, as upon the different Attraction of the Parts.

* See Part III. Chap. vi. Art. 13.

should

ſhould ſeem to follow from what was before demonſtrated concerning hard Bodies ſwimming in Liquids, becauſe every Particle of Salt or Metal is heavier than an equal Maſs of the Liquid in which it ſwims. However, it is to be obſerved, that when we reaſoned in that manner, we conſidered *only the Gravity of the hard Body*, and *the eaſineſs of the Liquid to be divided*; we did not then know of *the* 1 *Motion of the Particles of the Liquid*, by which they carry up with them as many Particles of Salt or Metal, as would deſcend by their own Weight; in the ſame manner as the Bubbling up of new Wine, makes other Bodies which are heavier, ſwim, and not ſink to the Bottom of the Tub; where we ſee that they do at laſt ſubſide and compoſe the Lees, when this Motion, which is greater than the ordinary Motion of the Liquid, ceaſes. To which may be added, that the Particles of the diſſolved Body are in ſome meaſure intangled with thoſe of the Liquid, which they go along with; which ſhows us more particularly that this hinders them from being able to ſink.

21. That a certain Quantity of Water will diſſolve only a certain Quantity of a hard Body.

21. And that which is remarkable here, is, that as the Particles of the Liquid are finite, and the Force by which they are agitated is limited; it muſt neceſſarily follow, that when they have once laid hold of as many Particles as they can contain, they cannot after that ſeparate any more, nor overcome the Reſiſtance of the remaining Particles which are at reſt; wherefore the hard Body will be no farther diſſolved. And thus we find by Experience, in common Water and *Aqua fortis*, that they will diſſolve but a certain determinate Quantity of Salts or Metals. Thus, for Example, if, after a Pint of common Water has diſſolved a certain Quantity of Salt, one Grain only be put in, it will continue whole in the Water, as it would do in a dry Place.

22. How the Chryſtalization of the Chymiſts is made.

22. And from hence it follows, that if after a Liquid has ſeparated all that it can from a hard Body, it be evaporated to a certain Quantity; that which remains will not be able to contain all the Particles of the diſſolved Body, wherefore many of them will be forced to unite together, and to compoſe ſomething ſenſible: And thus it is, that if Water be boiled, having firſt been ſtrained like Lye, through Earth charged with Nitre as much as it can be, and then taken off from the Fire,

1. *The Motion of Particles*) Not by their Motion, but by their Attraction. *See above on Art* 15.

and permitted to settle a little, a great many Particles of the Salt-peter which are disingaged from the Particles of the Water, will cease to move, and striking many of them together against the Concave Sides of the Vessel, will at last compose [1] those curious Bodies in the Form of Hexagons, which we see stick there. And in the same manner we may apprehend, how all the other *Christalizations* of the Chymists are made.

23. That the Water which will not dissolve one certain Body any longer, will yet dissolve a Body of another Sort.

23. Though *a certain Quantity of any Liquid*, will dissolve but a *determinate Quantity of a certain hard Body*, yet this does not hinder, but that other hard Bodies may be dissolved by the same Liquid; because their Particles may be of such a Figure, as to suit with the Particles of the Body already dissolved, in such a manner, as may occasion more dissimilar Particles, to move with greater Ease, than the similar Ones could move And thus Experience shows us, that after Water has dissolved as much Salt as it can, it will yet dissolve a small Quantity of Vitriol or Alum.

24. How the Precipitation of the Chymists is made.

24. If a Body be put into a Liquor, to whose Particles it will more easily unite it self, than to those of another Body which it had before dissolved; and supposing also that it cannot comprehend these two Sorts of Particles together, [2] it must be forced to let go the Particles which it had before embraced, which will consequently subside to the Bottom of the Vessel. Thus if a little of that dissolved Salt, which Chymists call *Oil of Tartar*, be poured upon *Aqua fortis* which before had dissolved Silver, the Metal will be forced to subside to the Bottom of the Vessel. And this Instance shows us the Reason of all the *Precipitates* of the *Chymists*.

1. *Those curious Bodies*) Concerning which the admirable Person before cited, says thus. *When any saline Liquor is evaporated to a Cuticle, and let cool, the Salt concretes into regular Figures; which argues, that the Particles of the Salt before they concreted, floated in the Liquor at equal Distances in Rank and File, and by consequence, that they acted upon one another by some Power, which at equal Distances is equal, at unequal Distances unequal. For by such a Power they will range themselves uniformly, and without it, they will float irregularly, and come together irregularly.* Opticks, p. 363.

2. *It must be forced to let go*) If such a Body be put into such a Sort of Liquor, that the Particles of the Liquor will be more strongly attracted by the Particles of this Body, than by the Particles of that Body which was dissolved in it before, the Particles of the Liquor being by this stronger Attraction removed from the first Body to this Other, will suffer the Particles of the first Body to sink to the Bottom, in the same manner as Iron is separated from a Loadstone, by putting a stronger Loadstone to it.

25. We must not here omit another Circumstance very considerable, and that is, that the Particles of *two Liquors* may be of such a Bigness and Figure, as to intangle one another when they meet together, and so move with more difficulty; whence it follows, that they will compose *One Body which is not so liquid*: So likewise, if the Particles of the two Liquors adjust themselves to each other, so that the greatest Part of them are hindred from moving, then all the Particles together will form a Body *pretty hard*. Thus we see, that if an equal Quantity of Spirits of Wine and Spirits of Urine, each of which Liquors are very fluid, be mixed together, they will unite into *a pretty hard Body*. *25. How two Liquors mixed together, may compose one hard Body.*

26. We may add to what has been said about the Mixture of different Liquors, that there may be found *one*, which is composed of such sort of Particles, that some of them being much larger than others, they cannot continue their Motion, but by means of the smaller ones; so that if these be any way disingaged, the Weight of the other alone, or the Irregularity of their Figure, will make them continue at rest with each other, and according as they are more or less closely united together, they will compose a *Body* more or less *hard*: And this is the Reason why some of the Particles of Milk or Blood curdle, while others which are more proper to continue their Motion, being disingaged from these, compose a *Serum*, which remains *liquid*. And this is also the Reason why, in subterraneous Caves, which they call *dropping Caves*, certain *liquid Drops* which distill from the Roofs harden into Stone, after they have been a little while in the open Air. *26. How a hard Body may arise out of a liquid one only.*

27. Having sufficiently shown by these Experiments, that the Particles of liquid Bodies are in continual Agitation, we are to enquire next, what the *efficient Cause* of this Motion is, first, in Water and other such like Liquids, which seldom grow hard, but more particularly in Air, which never hardens, but always remains liquid. Wherefore in the first Place it is reasonable to think, that the † Figures of the Particles of Liquids are not altered, so long as we cannot perceive any kind of Alteration in them: But further, because they cannot move with regard to each other, as they ought to do, to compose a Liquid, without leaving a great many Interstices round them; which there being [1] no Reason to think empty, they must necessarily be surrounded by some Mat- *27. Of the Causes of Liquidness.*

† For if their Figures were continually altered, there would be no need of subtil Matter to fill up their Interstices.

1. *No reason to think empty*) See the Notes on Chap. viii. Art. 2.

ter which is very ſubtle, ſuch as that which we before called the Firſt or Second Element. And as the Particles of hard Bodies diſſolved in any Liquid, are kept in Motion by the Particles of this Liquid; ſo we ought to think, that the Particles of Water, and of all Bodies which do not congeal, but always remain liquid, are in perpetual Agitation, becauſe they ſwim in the *Matter of the Firſt and Second Element*.

28. How Liquors are evaporated. 28. If this Matter be very much agitated, it is eaſy to conceive, that it may move the Particles of the Liquid in ſuch a manner, as to diſſipate them from each other, and make them fly into the Air, and this is called *Evaporation*.

29. How they are congealed. 29. On the other hand, if its Motion be very faint, or if it be more than ordinarily ſubtil, it will follow, that it will not be capable of preſerving the Liquidneſs of ſome groſſer Bodies; in the ſame manner as we ſee the Water running amongſt Bulruſhes, keeps them in Motion, and diſtinct from each other, whereas in the Air, they are confuſed and mixed together, without any Motion; [1] and thus the Water is *frozen* in Winter, and *turned into Ice*. But we cannot ſhow a Reaſon why this happens at one Time of the Year, rather than at another, till we come to know ſomething more of the Syſtem of the World.

30. Why ſome Bodies grow ſoft before they become liquid. 30. If the Diſpoſition of the Particles of a Body be ſuch, as to leave Pores between them large enough to receive the groſſer Matter of the Firſt and Second Elements, this Matter may ſhake the Particles a little, before it quite ſeparates them, and moves them from each other, and conſequently the Body *ought to grow ſoft, before it becomes liquid*, as we ſee *Wax* does.

31. Why other Bodies become liquid without growing ſoft. 31. But if the Pores of a hard Body are ſo ſmall, that only the moſt ſubtil Matter of all can paſs through them, in this Caſe, that which is more groſs, and which is alone able to ſhake thoſe Particles which make the leaſt Reſiſtance to it, can only apply it ſelf to the Superficies of the Body; whence it follows, that it will have diſſolved

1. *And thus the Water*) Since neither the Force it freezes with, is always proportion'd to the Cold, but ſeems to have ſome Dependance upon other Changes in the Heavens; nor is the Cold, unleſs ſo far as it is merely comparative (*See the Notes on Chap. xxiii. Art. 54.*) owing to the Particles being at Reſt; nor can Hardneſs it ſelf (*See the Notes on Art. 9. of this Chap.*) ariſe from the mere Reſt of the Particles: Congealing muſt neceſſarily be aſcribed either to nitrous Particles; or to the Particles of ſome other Salts, which like Wedges fixed between the Particles of Water, join them together and make them cohere: However there is hitherto nothing certain found out concerning theſe Particles.

all

all the external Parts of the Body, before it makes any Alteration within it. And so *such a Body will be entirely dissolved without being made soft*, as we find *Ice* does. *

32. It is not at all surprizing, that Water, which is liquid, should *soften* a great many hard Bodies which it penetrates and dissolves, and that, when it is mixed with Plaister of Paris, for Example, there should arise a Composition pretty liquid: But it is very surprizing, that afterwards it should acquire a *Hardness* which it would never have had without mixing Water with it, which one would think, should rather help to soften, than to harden it. Nor can we think, that this arises from a sudden Evaporation of the Parts of the Water; for if it be weighed when it is liquid, and weighed again when it is grown hard, we cannot perceive that it has lost any of its Weight. My Opinion concerning the Matter is this; that the Fire has formed a great many Pores in the Plaister, of such a Bigness, as the grosser Particles of the Air cannot penetrate, because they are not solid enough to remove the Obstacles they meet with, which the Particles of the Water, which are more solid and penetrating, are able to do. Wherefore, when the Plaister is moistned with, or put into such a Quantity of Water only, as is sufficient to surround every Grain or Lump of it; and after that they come to be stirred up together, then the Particles of the Water which force themselves into the Pores, like so many small Wedges opening and splitting them, divide these Grains into still smaller Parcels. And because these Parcels have a larger Surface than the Grains had before, of which they are but the Dust, it is more than the Water is able to surround. Insomuch, that the greatest part of them touching one another close, and continuing at rest, it is no wonder [1] if they compose a hard Body.

32. How Water hardens Plaister of Paris.

K 2 33. From

* The true Cause why some Bodies grow soft before they melt, and others not, seems to be this; that those Bodies which grow soft, are composed of dissimilar Parts, some of which melt sooner than those they are mixed with.

1. *If they compose a hard Body*) Mr. *Le Clerc* attacks our Author here with three Arguments in his *Physicks*, *Book* V. *Chap.* XIV. *Sect.* 25. *First*, says he, *This Answer does not agree with a Mass made up of Meal and Water kneaded together, and baked; and other such like Things that might be instanced in.* But can any Thing be more evident, than that the Evaporation of the water produces the same Effect in Bread, as the Dissolutions of the Lumps in Plaister of Paris? For though not all, yet certainly some of the Water is dissolved into Vapours, in proportion to the Heat, wherefore the external Part of the Bread is much harder than the Internal. *Secondly*, He says. *He does not show why the Particles of Water so divided touch one another close.*

But

33. *That too great a Quantity of Water hinders the Plaister from growing hard.* 33. From hence we draw this Consequence, that if the Plaister be put into such a Quantity of Water as is sufficient to surround all the small Parcels which the Lumps are divided into, they will be hindred from resting, and so the Plaister will not grow hard at all; and thus the *Masons* find it by Experience, and this is what they mean, when they say their Plaister is *drowned*.

34. *Why Water does not harden Lime.* 34. Notwithstanding this, it is not to be wondered at, if there be some Bodies which the Water will divide, and yet not at all help to unite and harden their Parts into one Mass, as it does those of Plaister of Paris; for the Particles of these Bodies may be of such a Figure, as scarce to touch one another at all, and so cannot unite together to compose one Whole: To which it may be further added, that the Water has so quick a Motion within some Bodies, that it disperses very much the disunited Particles; and by this means the Pores and Intervals, which are between them, become so large, that the Air has Power to get in, and hinder such Particles from touching one another. And this is the Reason why *Lime*, which is divided by Water, does not however become hard like Plaister of Paris: For if a Piece of Lime, which has been wetted with a little Water, be divided without meddling with

But he does expressly show this in these Words. *And because these Particles have a larger Surface than the Grains had before, of which they are but the Dust, it is more than the Water is able to surround; Insomuch that the greatest Part of them touching one another close*, &c. What could have been said more express? But (I suppose) this learned Gentleman, when he translated this Place into *Latin*, being not very attentive, overlook'd the connective Particle, *tellement que*. *Thirdly*, He says, *That he supposes Hardness to arise from immediate Contact and Rest, which we have before confuted.* Concerning this, See *the Notes on Art. the 9th of this Chap.* Having thus confuted the Opinion of our Author, the learned Gentleman conjectures, "*That the Particles of Water which dissolve the grosser Lumps of the Plaister, are so fixed into the lesser Particles, as, like Wedges to join many of them together, and so compose a more solid Mass.* But, if the Parts of the Plaister must be kept together by Wedges, it seems much more probable, that the burnt Parts (for the Plaister is made of Stone half burnt) growing a little hot, by the Water being poured on it, draw the volatile Salts out of the Parts which are not burnt, which Particles of the Salts being fixed in the Pores of the Plaister, keep its Parts together: For the stiff Particles of Salt, seem much more proper to perform the Office of Wedges, than the limber and flexible Parts of Water. But indeed, Plaister of Paris, Clay, and such kind of Bodies, do therefore grow hard in this manner, because the Water in evaporating, so attracts their Parts to each other, which before did not touch one another, that afterwards touching one another in larger Superficies, they cohere together by that mutual Attraction, which depends upon immediate Contact. *See the Notes on Art. the 9th of this Chap.*

it,

it, the Dust into which it dissolves it self, is of two or three times as much Bulk as it was before.

35. When the Water penetrates the Pores of certain Bodies which it cannot entirely divide; it is evident, that it will stop for some time; because it must lose its Motion, by striking against the Particles which it touches: But it is otherwise with *the Matter of the First and Second Element*, when it passes through the Pores of hard Bodies: For as these Pores, as small as they are, are formed by its continual passing through them, so it leaves them big enough always to find a Passage through, without ever being stopped. *35. That the Matter of the First and Second Element does not stop in the Pores of hard Bodies.*

36. However, it is to be observed, that by bending a hard Body, such, for Example, as the Blade of a Sword, the Particles will be made to expand themselves on the Convex Side, and to contract themselves on the Concave Side, so that its Pores will become smaller and streighter on this Side; but this ought not to hinder the Matter of the First or Second Element from entring in, because being very fine, and moving very quick, it ought rather to alter its own Figure and become longer, or to wear in pieces the Matter which streightens it, than to be hindred in its Passage; and so the Pores will not be stopped up by it. *36. What the Consequence of the Matter of the Second Element passing through very small Pores ought to be.*

37. But because the subtil Matter which passes through the Pores which are so very small, cannot endeavour to wear the Particles of the hard Body through which it passes, but it must at the same time endeavour to restore the same Particles to the State they were in before the Body was bent; it follows, that this ought to make the Body grow streight again. And thus we experience the Property which is called *Stiffness*, and which Workmen call 1 *the Power of Springing.* *37. What the Force of springing back consists in.*

38. However, this Property ought not to be found in all Sorts of hard Bodies indifferently; because there are some, whose Pores are so large, that though they be streightened by bending the Bodies, yet they will be still *38. Why it is not found in all hard Bodies.*

1. *The Power of Springing*) Since this subtil Matter, as was before proved, is only fictitious, it is much more probable, that if a Body be compounded of such Sort of Particles, that it be *compact, and bends or yields inward to Pression without any sliding of his Parts, it is hard and elastick, returning to its Figure with a Force arising from the mutual Attraction of its Parts.* Newt. Opt. pag. 370. But if the Parts of the Body slip under one another, then the Body is of that Sort, which will yield to the Stroke of a Hammer; But concerning the Laws of the Communication of Motion, in such Bodies as have *a Power of springing back*, or are *Elastick*, as they call it, when they meet others, with certain Forces. *See the Notes on Chap.* xi. *Art.* 6.

wide enough to give a free Paſſage to the ſubtle Matter. Thus we can perceive by our Senſes, that the Parts of Steel which is not tempered, are larger, and conſequently the Pores wider, than thoſe of tempered Steel; whence it is eaſy to apprehend that the Pores may be ſtreightned, without hindring a free Paſſage of the ſubtle Matter through them; whence it follows, that when it is bent, it will not ſpring back again.

39. Why a Plate of Iron becomes Elaſtick, by being beaten, when it is cold.

39. Now to ſhow, that the *Power of Springing* conſiſts intirely in the ſmallneſs of the Pores of a hard Body; let us conſider, that if a Plate of untempered Steel, be beaten upon an Anvil when it is cold, it will acquire a Power of Springing which it had not before. But it is manifeſt, that this Beating does nothing elſe but make the Parts approach nearer one another, and by this Means ſtreightens the Pores: whence it follows, that herein conſiſts this Power.

40. How this Power may be loſt.

40. It may be further obſerv'd, that if a Spring be held bent a long time, without being allowed to recover it ſelf, the ſubtil Matter will be forced to alter its Figure by growing longer, if it be *not able* to wear in pieces the Matter of the hard Body: or if it *be*, the Pores will grow bigger and bigger, ſo as that the Matter of the Firſt and Second Element may paſs freely through them; and this is the Reaſon why the Body ought to loſe the Power of recovering it ſelf, in proportion as it is capable of being worn; which agrees with Experience.

41. Whence the Force with which a Spring unbends it ſelf, ariſes.

41. The Force with which a Body unbends it ſelf, depends partly upon *the Swiftneſs of the Motion of the ſubtil Matter*, and partly upon *the great Number of Pores through which it paſſes at a time*: But it depends chiefly upon *the Diſpoſition of theſe Pores as they become inſenſibly ſtreighter and ſtreighter*. For by this means, that which gets into them ought to have the ſame Force, and to produce the ſame Effect, as a Body which paſſes between two others whoſe Superficies are almoſt parallel. Now according to the Laws of Mechanicks, though the Body which thus paſſes between two others be very ſmall, and moves but ſlowly, it will notwithſtanding, have an incredible Force to ſeparate thoſe two from each other.

42. Why ſome Bodies break in reſtoring themſelves.

42. When the ſubtil Matter begins to remove the Parts of the Body which are in its way, it has their whole Reſiſtance to overcome, and alſo ſome of the Reſiſtance of the ſurrounding Bodies: Now becauſe every Thing endeavours of itſelf to continue in that State in which it once is, and therefore the Bodies which have received a

certain Motion, continue of themſelves in that Motion; this ſubtil Matter cannot continue to impell them, but it muſt increaſe their Motion; and it may ſo happen, that by its impelling and moving them in this manner, it may ſo far divide the Particles of the Body, through which it paſſes, from each other, as entirely to ſeparate and break them; eſpecially if the Body be brittle.

43. VVhat the Limberneſs or Brittleneſs of a Body conſiſts in.

43. Now in order to underſtand how it is, that ſome Bodies will *bend* without breaking, and that on the contrary, others will very eaſily break: it is to be obſerved, that the Texture of ſome may be ſuch, that their Particles may be intermixed with each other, like the Rings of a Chain, or the Threads of which a Cord is compoſed. Now it is eaſy to conceive, that theſe Bodies may be wound ſeveral times round without breaking, becauſe their Particles are ſo hooked together, that they may be bent any way. On the other hand, there may be Bodies which are not of ſuch a complicated Texture, which are hard only, becauſe their Particles touch one another in a few Places: Whence it follows, that one cannot ſeparate them ever ſo little, but their whole Continuity will be deſtroyed; and theſe are what we call *brittle* Bodies.

44. VVhy the Place in which a limber Body breaks, is very unequal; and that of a brittle Body very ſmooth.

44. Leather may ſerve for an Inſtance of a *limber* Body, that is, of a Body that will bend without breaking; and Glaſs, on the other hand, for an Inſtance of a *brittle* Body; that is, one that will break before it will bend: And there will be no doubt, but that the *Limberneſs* of the one, and the *Brittleneſs* of the other, conſiſts in what I have ſaid; if we conſider the Place where a Piece of dry Leather is pulled aſunder, and the Place where a Piece of Glaſs is broken: For the Leather appears unequal, and as it were untwiſted, which is an evident Sign, that the Particles which are at the End of one Part, entered in between the Particles which are at the End of the other Part; and on the contrary, the Breach of the Glaſs appears very well poliſhed, which is a Sign, that the Particles of one of its Pieces, touched the Particles of the other Piece only, without entering in between them.

45. VVhy Glaſſes newly made, are apt to break, without being meddled with.

45. If Glaſs, which is very brittle, have very large Pores on one Side of its Superficies, and which grow leſs and leſs towards the other Side; there cannot enter into theſe large Pores, ſubtil Matter enough to fill them, but that by continuing its Motion very quick towards the ſtreighter Parts of the Pores, it muſt wholly diſunite the Parts. Now when a Drinking-glaſs, which is juſt made,

grows cold on a ſudden; it is impoſſible but that the Pores muſt be larger where the Glaſs is thickeſt; becauſe the Heat, which dilate Bodies, continues longer here than in the other Parts: Wherefore the ſubtil Matter which enters into theſe large Pores, going on ſwiftly, and with great Force, [1] muſt break the Glaſs in the Places where the Pores are ſenſibly leſs. And this ſo commonly happens, that it is ſomething ſtrange, if a hundred Glaſſes be expoſed to the Air as ſoon as they are made, if one of them eſcape without breaking.

46. To hinder Glaſſes from thus breaking.

46. The Glaſs-makers have a Way to prevent this Inconvenience, by putting the new-made Glaſſes into the Arch of the Furnace, where they are removed by little and little out of the Flame, ſo as not to get above the Space of nine or ten Foot, in ſix Hours time, and then they are expoſed to the open Air; and ſo all the Parts growing inſenſibly Cold, the one as well as the other, the Pores become equally ſtreight every where, and the ſubtil Matter which can enter into one of them, can run from thence freely, through all other Parts of the Glaſs where the Paſſages are equally open.

47. A ſurprizing Property of a Glaſs Drop.

Tab. III. Fig. 5.

47. What we have now ſaid concerning the Cauſe of Glaſſes being broken as it were of themſelves, opens a Way for us to explain a kind of a Miracle in Nature, which was lately diſcovered and brought hither from *Holland*, and which has travelled through all the Univerſities of *Europe*, where it has raiſed the Curioſity, and confounded the Reaſon of the greateſt Part of the Philoſophers. It is a kind of a *Drop* of thick Glaſs, and ſuch as the Glaſs-Windows are made of, near the ſame Shape and Bigneſs as deſcribed in the Figure. It is entirely Solid, except perhaps we may ſometimes ſee a few ſmall Bubbles of Air in the thickeſt Part of it, as at D, where it will bear pretty hard Blows of a Hammer without breaking. And yet, if the little End of it be broken off any where near B, the whole Body will burſt in Pieces with a Noiſe; and we ſhall ſee it ſcatter it ſelf all round,

1. *Muſt break the Glaſs*) But it may be (and it is more likely) that the Cold, by ſtopping the Motion of ſome of the Parts on a ſudden, whilſt the reſt are in great Motion, breaks Veſſels made of Glaſs. For thus almoſt all Bodies are broken by the unequal Motion of their Parts: Hence a Tile by one Blow burſts aſunder many times into two or three hundred Pieces. Hence the Chymiſts Veſſels are often broke. Hence they who cut Drinking-Glaſſes into Spirals, firſt put a red hot Iron near them, and then pour cold Water on the Part of the Glaſs which is heated. And hence Drinking-Glaſſes are reported to be broken only by the Voice bending them.

and

and to a good diſtance, in a Powder, which though very ſmall, has its Parts cracked in ſo many Places, that it is eaſy to divide them by preſſing them between ones Fingers; which may be done without any Danger of pricking them, as there is, if we ſhould handle a piece of Glaſs ſo, after it is powdered in a Mortar.

48. To ſay the Truth; this *Phænomenon* is ſo ſingular, that it is no wonder it ſhould at firſt Sight ſurprize us. But if we conſider it more cloſely, it is eaſy to obſerve, that there is nothing elſe appears, but only the *local Motion* of the Parts of the Body, which are carried from the Center to the Circumference: Now as we cannot conceive how a Body ſhould begin to move of it ſelf, without being put in Motion by another Body which was in Motion before; ſo it is eaſy to imagine, that the ſcattering about of the Particles of the *Glaſs-drop*, is owing to ſome Matter which getting into its Pores, preſſes upon them and divides them, in the ſame manner as we ſee a Wedge when it is driven into a Body with great Force and Velocity, ſplits it, and ſeparates the Parts from each other. And there is no Doubt at all, but that this is the ſame Matter which breaks the Glaſſes in the Glaſs-Houſe, when they are ſuffered to cool too ſoon.

48. Of the external Cauſe of the Motion of the Parts of the Drop.

49. Now in order to underſtand how this *Drop* could acquire a Diſpoſition proper to produce this Effect, there is Reaſon to gueſs, that the Workman, who makes a Secret of it, has a Way of cooling it all at once, by dipping it when it is very hot into ſome Sort of Liquor, which hinders it from breaking in pieces: For we ſee by Experience, that Glaſs which is ſo cooled in Water, breaks into ſmall Pieces. But be this Liquor what it will, it is certain, that the Parts of the *Drop*, which are neareſt the Surface, cool firſt, and by communicating their Motion to this Liquor, loſe what they had before, which kept them at a little diſtance from each other; and ſo they are condenſed, and contract their Pores, and fit them to the fineſt Parts of the ſubtil Matter, which preſerves its Paſſage through them. But this is not the Caſe of the internal Parts of the *Drop*, which not being cooled till after the other, cannot contract themſelves ſo, becauſe thoſe other being grown hard, and diſpoſed like an Arch, do not at all preſs upon them; ſo that the Pores which are amongſt the Parts neareſt the Middle, are large, and grow leſs and leſs as they come towards the Superficies. And this being allowed, there is a plain Reaſon for what cauſes ſo great Admiration.

49. What the particular Diſpoſition of the Parts of the Drop ought to be.

50. It

50. *That it ought to bear the Blows of a Hammer.* 50. It is no wonder that the *Drop* will bear the Blows of a Hammer, becaufe it is thick enough for that: For other Pieces of Glafs of the fame Bignefs will do the like.

51. *That they ought not to break of themfelves.* 51. It is alfo manifeft, that they ought not to break of themfelves, as the forementioned Glaffes do, becaufe the fubtil Matter which paffes through them, finds as free a Paffage to come out, as to enter in.

52. *How it flies in pieces.* 52. But when the little End is broken off near the place marked B, we can there fee very large Pores into which the larger Particles of the fubtil Matter entring in a great Quantity, and continuing to move from thence very fwiftly, towards every part of the Superficies, where the Pores grow ftreighter; they cannot but 1 feparate every way the Parts of the Glafs, and fo divide them into that Powder which we fee.

53. *Why it does not break in pieces when the very End of all is broken off.* Tab. III. Fig. 5. 53. This Truth is confirmed by obferving, Firft, That the Extremity of all, which is at A, is fo fmall, that there could be no fenfible difference in cooling between the infide and the outfide, fo that the Pores there are of an equal Bignefs throughout. Wherefore if the End be broken off thereabouts, this will not give leave to the fubtil Matter to let in its groffer Particles, any more than if it were not broken at all, and confequently the *Drop* ought not to burft in Pieces; as by Experience we find it does not.

54. *That the Drop, when beaten again, ought to lofe its Vertue of burfting afunder.* 54. Further, if one of thefe Glafs *Drops* be made red hot in the Fire, and then fuffered to cool flowly, its Pores will then become very near equal, in like manner, as Workmen neal Steel. After which, if the End of the *Drop* be broken off any where, becaufe there can no fubtil Matter enter in, but fuch as can go out on all Sides with as great Eafe as it entred in, therefore the *Drop* 2 ought not to burft in Pieces at all; which alfo we find true by Experience.

1. *Separate every way*) Becaufe Glafs is a Body which has a Power of Springing; it is probable, that this Glafs Drop is broke in the fame manner, as a Steel Bow burfts in pieces fometimes, when it is loofned on a fudden; *viz.* by the too great Celerity and Force of that Motion which arifes from the mutual Attraction of its Parts. For its Parts from the Center to the Circumference, feem to be like fo many Bows bent And hence perhaps it is, that after it is burft in Pieces, its Fiffures are difpofed like fo many Radii drawn from the Axis to the Superficies, as Mr. *Hook* obferved in a Glafs Drop covered over with Glue. See *Hook's Micrography Obferv. 7th.*

2. *Ought not to burft in pieces*) For the fame Reafon, that there is no danger of breaking a Bow when it is gradually loofned.

55, Laftly,

55. Laftly, To confirm what has been faid of the Inequality of the Pores which are in the Middle, and thofe near the Superficies in thefe Sort of *Drops*, I carried three of them to three different Lapidaries: The firft of them I ordered to cut the *Drop* which I gave him, with Powder of Diamond about the Place C. I ordered the Second to drill a Hole in his, with the fame Powder about D, and I ordered the Third to put his upon the Wheel, and grind it plain at E, with Powder of Emery: Now after thefe three Workmen began feparately to work upon them with as much Caution as they do upon Pearls or Stones of a great Value, and had ground with thefe Powders as much off from the *Drops* as amounted to the Thicknefs of a *French* Two-pence, which I reckon is as far as the fmall Pores reach, I faw each of them burft in pieces as ufual, to the great furprize of the Workmen, who did not at all expect any fuch Thing. *55. Some curious Experiments of Lapidaries.* Tab. III. Fig. 5.

56. But to return now to the Confideration of Liquids. I obferve firft, That if they be all reduced to two Species, the one comprehending all thofe which we call *thin*, and the other, all thofe which we call *fat*, it will not be difficult to determine what their principal Difference confifts in. For fince the former is very eafy to evaporate, but the Latter evaporates with great Difficulty, we cannot but think, that the Particles of the one, muft be of very fimple Figures to be able to difingage themfelves from each other, and the Particles of the other, of more entangling Figures, fomething like Branches of Trees, by which they hold each other together. *56. Of two principal differences in Liquors.*

57. And this is confirmed from hence, that if a Veffel full of *thin Liquor* be fo inclined, as to pour it out flowly, the Liquor will run about, and divide itfelf into a great many diftinct Drops; whereas if it be a *fat Liquor*, it will go on in a long Thread, whofe Parts are uninterrupted. *57. Why Water, when poured down, is difperfed in Drops.*

58. This being fuppofed, we fhall not think it at all ftrange; that Oil or Air is fo hard to mix with Water: The Reafon of which is, becaufe the Particles of thefe Liquors unite together much eafier than they do with the Particles of the other: Whence it is, that if Water and Oil put into the fame Veffel, be fo fhaked up together, that they feem to compofe but one Liquor, they cannot continue fo long, before the Particles of the Oil which meet each other, will entangle themfelves fo as to compofe feveral Drops, which becaufe of their Lightnefs, rife up, at the fame time that the Particles of the Water, whofe Motion *58. Why fome Liquors will not mix together.*

Motion causes them also to meet, join together likewise, and compose other Drops which sink downwards: And this is the Reason why these two Liquors entirely clear themselves of each other, and become distinct, the one at the Top, and the other at the Bottom.

59. *That the Drops of one Liquor which swim in another Liquor, are round.* 59. It is worth observing, that *the Drops of Liquors, which swim in a large Quantity of other Liquors which they will not mix with, are all round like Balls.* This cannot be perceived in Drops of Rain as they fall in the Air, by reason of the Swiftness of their Fall; on the contrary, they ought rather to appear long, so, as we should take them for small Columns; for the same Reason that a lighted Torch moved quick, appears like a long Train of Fire. A better Way then for us to take, in order to see if the Drops of Water which swim in the Air be round, is to put a little Water into the Hollow of one's Hand, and to throw it up into the Air, about the Height of our Eyes; for then it will divide it self into a great many small Drops, which beginning to descend very slowly, give the Spectator an Opportunity of observing their Figure.

60. *The Opinion of the* Aristotelians *concerning the roundness of these Drops.* 60. This *Phænomenon* has always been observed, and a Reason for it attempted to be given, by saying, that the Parts of the same Liquor have *a mutual Affection for each other*; whence follows *a Desire of uniting together*, which cannot be done perfectly, but by composing a Ball; for if they composed any other Figure, those Parts which were most distant from the Center, would tend towards it with a greater Force than those which are nearer it, and consequently make them give way, and remove back till they are all equally placed about the Center, and so become round.

61. *A Confutation of the Opinion of the* Aristotelians. 61. But because these Words, *Affection* and *Desire* have no Meaning, that we can apprehend, unless they be ascribed to Subjects which are capable of Knowledge; therefore we cannot apply them to the Parts of Water, without speaking very improperly and obscurely. Wherefore, these are so far from explaining a Thing which ought to be very easy, (for we are only inquiring into the Figure of a Body;) that they perplex it with Terms which have no clear and distinct Signification when applied to such Subjects. Further, let this *Desire of uniting* be explained how it will, it is very absurd to ascribe it to Subjects which seem naturally to be fitted to *disunite from each other*, because Nature has made them so capable of disuniting.

62. In

62. In order then to find out the Cause why the Drops of Liquors which swim in other Liquors are round, we must keep this Truth in our Minds: *That every Thing endeavours, as much as it can, to continue in that State, in which it once is*; and consequently, *that* which is once in Motion, would continue to move with the same *Determination* with which it began, that is, according to what was before said, in the same streight Line. Thus, if the Body A, for Example, is moved along the Line AB, it is determined at the Beginning of this Motion to go towards C, and it will never of its self tend to go towards E or towards D. However, if when the Body is come to B, it meets with any Obstacle there, it may turn out of the Line BC and go in some other Line. But because it is forced out, it follows, that it will go as little out as it can, that is, when it quits the Line AB at the Point B, it will tend to move in a Line which will make the least Angle that can be conceived with the Line BC. And because the Line BD does not make so small an Angle with the Line BC as BE does, we cannot but think, that the Body A tends rather to move in the Line BE than in the Line BD. And because the Circumference of a Circle, of which BC is the Tangent, makes a less Angle with BC than any Angle comprehended betwixt two streight Lines; we must conclude, that the Body A, when it is arrived at the Point B, will resist turning into the Circumference of a Circle less than into any streight Line. Lastly, Because it is certain, that the Circumference of a great Circle makes a less Angle with its Tangent, than the Circumference of a small Circle does with its Tangent, we must also conclude, that the Body A, when it is arrived at the Point B, where it is forced to turn out of its Way, will resist still less, the describing the larger Circumference BG, than the smaller one BF.

62. That Bodies which are compelled out of the way, tend rather to describe the Circumference of a Circle than a streight Line, and the Circumference of a larger Circle rather than of a smaller.

Tab. III. Fig. 6.

63. This being so; if the Particles which compose a Drop of Liquor, and which are hindred from going on in their Motion, by the Liquor which surrounds them, be compared to the Body A; and all that has been said of the Body which made Resistance to it at B, be applied to the Particles of the surrounding Liquor, which do not make so great Resistance, but that they can retire back a little; we conclude, that the Particles of the Drop, do gradually remove those surrounding Particles which get within the Sphærical Superficies which the Drop may be com-

63. Why the Drops of Liquors are round.

comprehended under: And becauſe [1] the World is full, and the Particles which are removed out of their Place, have no where to go, without removing as many others, they muſt neceſſarily be driven to thoſe angular Parts of the Drop which are without that ſphærical Superficies; and ſo the Drop will of it ſelf become of a round Figure, though the ſurrounding Liquor contributed nothing elſe to it, but only not reſiſting it at all: But becauſe the Particles of this Liquor, are more hindred from continuing their Motion in a ſtreight Line, by the angular Parts of the Drop, than by the others which are nearer the Center, it is evident, that they muſt force them towards the Center, and at the ſame time make theſe other remove further off from it. [2] And in this manner the ſurrounding Liquor contributes as an efficient Cauſe, towards making the Drop round. Nay, we may affirm, that it does the greateſt Part towards it, if, all other Things being alike, this be moved with the greateſt Celerity.

64. That Drops, any way ſupported, ought to be a little flat.

64. But it is to be obſerved, that there are two Things required in order to make Experience agree with this Demonſtration: The Firſt is, That the ſurrounding Liquor be not more than uſually agitated by any external Force; and Secondly, That the Drops be not any way ſupported, at leaſt, when they are of any conſiderable Bigneſs; for then their Weight, which is ſuperior to the Cauſe which makes them round, will make them a little flat, ſo that they will be round only in that Part which is parallel to the Horizon. As we ſee by Experience in Drops of Water

1. *The World is full*) See the Notes on Chap viii.

2. *And in this manner*) A Portion of any Liquor, incloſed in another Liquor, which it does not mix with, will preſerve its Figure, whatever it be, without any Alteration, if the Parts of the ſurrounding Liquor be at reſt, with reſpect to each other. See *Newt. Princip. Book* II. *Prop.* 20. *Cor. 9th.* But if the Parts of the ſurrounding Liquor be agitated, the incloſed Drop muſt neceſſarily be compreſſed into a globular Figure. For ſince the Superficies of any other Figure is greater than that of a Globe, and therefore expoſed to more Attacks from the Parts with which it does not mix, coming upon it on all Sides; and becauſe whatever is preſſed upon on all Sides, retires thither where it may be leaſt preſſed upon; it is evident, that the Parts of the incloſed Drop, muſt gather themſelves into the Form of, a Globe, when they will be leaſt preſſed upon. And this they will do, if there were no ſuch Thing as Attraction. But ſince the Drops of Water and of other Liquors, gather themſelves into a round Figure, in a *Vacuum*, as well as when incloſed in any Liquor, the Cauſe of this ought by all means to be aſcribed to the mutual Attraction which there is betwixt the Parts of one and the ſame Liquor. (*See the Notes on Chap.* xi. *Art.* 15.) For *the Drops of every Fluid affect a round Figure, by the mutual Attraction of their Parts: In the ſame manner as the Globe of the Earth and the Sea affects a round Figure, by the mutual Attraction of its Parts by Gravity.* Newt. Opticks, pag. 370.

which

which reſt upon ſuch Leaves of Herbs as they will not wet, and in thoſe put upon a duſty Table; as alſo in Drops of Oil or melted Greaſe ſwimming on Water, which indeed are not round, but only on that Side which is level with the Horizon, for on the other Sides, they are flatter in proportion to their Bigneſs and Weight.

65. This laſt Obſervation ought to be underſtood only upon Suppoſition, that all Things elſe are alike. For it is not at all impoſſible, but that of two Drops of different Liquors, that which is the moſt heavy, may be the roundeſt, provided it be alſo the ſmalleſt: The Reaſon of which is, that all the Particles of the Liquor which ſurrounds the Drop, do not help to make it round, but thoſe only which are applied to the Surface of it; the reſt, which enter into the Pores, help rather to diſſipate it. Wherefore a Drop, which is ſmaller and heavier, having its Pores leſs, and perhaps a leſs Quantity of them than the other, which is larger and lighter; has alſo its Surface more continued, and conſequently gives more Opportunity to the Cauſe, which makes it round, to work upon it, and leſs to that which would diſſipate it. Thus we ſee, that a Drop of Quickſilver is always more round than a Drop of Water a little lighter. *65. Why Drops of Quickſilver are more round than Drops of Water.*

66. On the contrary; Spirits of Wine, being very light, muſt have ſo many Pores, and the Superficies of it muſt be ſo interrupted, that there can be but a very few Particles of the Air applied to it to make it round, the greateſt part of them paſs through it, and tend to diſſipate it; alſo this is a Liquor, which it is very difficult to diſtinguiſh into Drops, as may be tried, by putting a little of it into our Hand and throwing it up into the Air; for if it be well *rectified*, it will not fall down in Drops, as Water does, but it will be ſo diſſipated by the Air, that none of it will appear ſenſibly on the Ground. So alſo if it be thrown upon a duſty Table, it will not gather into rounds Drops, but ſpread it ſelf about, and mix with the other Bodies which it meets with; nay, even with Soot it ſelf, which Water will not moiſten. *66. Whence it is that Drops of Spirit of Wine don't make themſelves round.*

67. Having thus ſhown what kind of Superficies that which is common to two Liquors, the one incloſed in the other, is; it may not be amiſs to ſtop a little, and examine what ſort of Superficies that ought to be, which is between two Liquors, the one contained in a Veſſel, and the other not: But becauſe there may be ſome Difference in this, according as the Veſſel will be wetted or not wetted by the Liquor contained in it; it is to be obſerved, that a Liquor therefore *67. Why a Liquor will moiſten ſome Bodies and not others.*

fore wets a hard Body, because it immediately touches its Superficies; and that another Liquor does not wet it, because it does not immediately touch its Superficies; but there is room left for the subtil Matter to pass between the concave Superficies of the one, and the convex Superficies of the other.

68. That the Superficies of the Water in a clean Glass exactly full, is quite flat.

68. This being supposed; we conclude first, that if a very clean Glass, whose upper Edge is of an equal Height all round, be *exactly filled* with Water, the Surface of the Water will be perfectly level and plain; because the Air which touches it, does not press more upon one Part than upon another.

69. That the Superficies of a Liquor which will wet a Glass, ought to be Concave, if the Glass is not full. Tab. III. Fig. 7.

69. But if the Glass be not full of Water, the Superficies ought to be Concave; [1] because the Air which comes in at the Mouth of the Glass, and circulates about the Glass and the Water, as if they were one continued Thing, cannot so easily turn to move along the internal Superficies of the Glass, as continue its Motion in the Middle: From whence, being to go out again at the Mouth of the Glass, it describes a Curve in a contrary Position, to what it did when it entered in, much the same as is described in the Figure; so that the Water is pressed more in the Middle than on the Sides, and consequently must rise towards the Sides.

70. Why the Concave Superficies is not spherical.

70. Experience would perfectly agree with this Reasoning, were it not that as the most convenient Motion for the Air is in a Circle, it should seem, that it ought to bend the Surface of the Water into the Form of a Concave Sphere, which yet it does not do; For the Surface of the Water is curved only towards the Sides, and is perfectly level in the Middle. But the Reason is plain; for if the Glass be large, a great Quantity of Water must be raised up to make the Curvature so convenient, as the Water requires, which it is certain is resisted by its Weight.

71. That the hollow Surface of the Water in a small Tube not full, is spherical. Tab. III. Fig. 8.

71. And for Proof of this; If into a small Tube of Glass, in which a small Quantity of Water rising at the Sides makes its Surface spherical, some Water be poured, so as not to fill it; we may observe, that it will continue in *the same manner Spherical*, though the Tube be inclined as you see in the Figure, where the Curvature

1. *Because the Air*) Since all these Phænomena are the same in a *Vacuum* as in the open Air; we must assert, that the Superficies of any Liquor contained in any Vessel is Gibbous or Concave, according as the Particles of the Liquor are more or less mutually attracted by each other, than they are by the Matter of which the Vessel is made.

ABC repreſents the Surface of the Water, which is therefore above the Level, and manifeſtly higher at A than at C, becauſe that Poſition of the Water agrees better with the Motion of the Air, which would be more turned back, and with greater Force in the Place D, if the Water were more upon the Level DBE.

72. The ſame Cauſe, which hinders the Water from growing level in an inclined Tube, hinders a Bottle alſo which has a very ſtreight Neck from emptying it ſelf, when it is near inverted, and the unequal Height of the two Parts of the Water which endeavour to come out at the ſame time, ſhould ſeem to deſtroy the *æquilibrium* of the Air's Preſſure, which repels and ſupports it by its Weight. For Example; Though in the Bottle here deſcribed, the Height of the Water which endeavours to come out of the Bottle at C, is greater than of that at A, and therefore ſhould ſeem to be able to force the Air to deſcend at C, and to riſe again by A, and get into its Place; yet this does not happen, becauſe the Parts of the Air now deſcribe the Curve ABC; and the Difference of the Weight of the Water at A, above that at C, is ſo very ſmall, that it is not able to make the Air to deſcribe a Line that is more curved, as it muſt do, if the Water which deſcends by C, took up part of the Width of the Neck.

72. Why a Bottle with a ſmall Neck, when filled full of Water, and turned with the Bottom upwards, will not empty it ſelf. Tab. III. Fig. 9.

73. If a little more Water be poured into a Glaſs of the common Shape, than will fill it exactly full; as that which would run over the Sides, is more expoſed to the Power of the Air than any other Part is; it follows, that the Air ought to puſh it back towards the Middle, where it ought to be higher, in order to its more convenient Motion. And thus we ſee that a Glaſs may *be filled heaping full,* and that the leſs the Glaſs is, the nearer does the Superficies of the Liquors it contains approach to a Sphere; becauſe it does not ſuſtain the Weight of ſo great a Quantity of Water, and the Force of the Air is ſufficient to bend it in this.

73. That the Superficies of a Liquor, when the Glaſs is heaping full, ought to be convex.

74. If the Glaſs be *greaſy*, or for any other Reaſon will not be *made wet*; whatever Quantity of Water be put into it, [1] the Superficies ought always to be convex; becauſe its Figure does not ſo much depend upon the external Air, as upon the Air that flows between the internal

74. That the Superficies of Water, in a Glaſs not full, and which will not be wetted, ought alſo to be convex.

1. *The Superficies ought always*) Thus the Superficies of Quickſilver in Glaſs Tubes, is always gibbous, becauſe it does not wet the Glaſs, but in Veſſels of Gold that are not full, its Superficies is concave, as that of Water is in Glaſs. *See the Notes on Art. 69. above.*

nal Parts of the Glaſs, and the external Parts of the Liquor which it contains, which by its continual moving round, blunts the external angular Parts which reſiſt its Motion, and forces them towards the Middle, or elſe forces them inwards, and ſo cauſes the Water to raiſe it ſelf up towards the Middle, where the Air oppoſes its Paſſage leſs, becauſe it cannot get thither, but by altering and bending its Courſe.

75. Why ſome Bodies floating on the Top of the Water, are carried from the Middle to the Sides.

75. From what has been ſaid in the two foregoing Articles, we infer, that the Air which depreſſes the Middle of the Superficies of the Water in a Glaſs not full, ought from the ſame Cauſe, to drive light Bodies which ſwim upon it, and touch it immediately, *towards the Sides*: This I have experienced in ſmall Globules of Glaſs full of Air and cloſed up, which an Enameller made as light for me as he could; for theſe being put towards the Middle of the concave Superficies of the Water in a ſtrait Glaſs not very full, it was very pleaſant to ſee them driven from thence to that Side of the Glaſs which was neareſt to them.

76. That this Motion is not cauſed by Attraction.

76. Becauſe I made uſe of a ſmall Globule of Glaſs, and a Veſſel of the ſame, in this Experiment, ſome Perſons perhaps, may imagine, that this Globule moved towards the Side, becauſe it was attracted by the Glaſs: But it is very eaſy to confute this Imagination; for not to mention the Obſcurity of that Word, the ſame Thing will happen in a Veſſel of Wood, or of any other Matter whatſoever, [1] which we cannot ſuppoſe to have any Sympathy with the Globule.

77. That the ſame Bodies ought to go from the Sides towards the Middle in a Glaſs heaping full.

77. But that which evidently overthrows this Opinion, and confirms that which I have advanced, is, that if Attraction had any Thing to do here, the Globule ought to move ſwiftly from the Middle to the Side of a convex Superficies of the Water in a Glaſs heaping full; for beſides the Attraction, the Declivity ought to help its Motion. Which yet is not ſo; but on the contrary, it moves from the Side towards the Middle, as it ought to do, if what I have affirmed be true; becauſe, as was ſaid before, it is the Sides which are moſt expoſed to the Force of the Air; and the ſame Cauſe which drives the Water from the Sides to the Middle, ought alſo to drive the ſmall Globule.

1. *Which we cannot ſuppoſe*) See the Notes on Chap. xi. Art. 15.

78. But

78. But it is to be obferved in thefe Experiments, that the Body which floats on the Top of the Water, muft immediately touch it, or which is the fame Thing, muft be wetted by it, that the Air may be forced to move round them both, as if they were one continued Body. But if the Body which floats on the Water does not immediately touch it, or is not wetted by it, we experience the contrary; that is, the Body will defcend *from the Sides towards the Middle*, when the Superficies of the Water is *concave*, and *from the Middle towards the Sides* when the *Superficies* is convex, becaufe the Parts of the Air which pafs under the Body deprefs the Liquor all round, which produces the fame Effect, as if, when a large heavy fpherical Body was fixed upon the Declivity of a Mountain, we fhould take away the Earth equally all round it, and put Leavers under it to fupport it; for it is evident, it would by that means be difpofed to defcend to the Bottom of the Mountain.

78. Why a Body that is heavier than Water, when fwimming on the Top of the Water, does the contrary to a fmall Globule of Glafs.

79. It is to be obferved further, that when a Body which weighs more than an equal Bulk of Water fwims upon the Water, as a Needle made of Steel will do, the Reafon of it is this; that the Air which preferves it felf a Paffage between the Body and the Water, fupports it and hinders it from finking: For we ought not to think that it proceeds from hence, that the Parts of the Water are harder to be feparated near the Superficies, than deeper in, as we may be apt to imagine; for having caufed fome fmall Needles to be made of Glafs, which were lighter than the Steel Needles of equal Bignefs, and laid them gently upon the Water, they always funk down to the Bottom.

79. How fuch Bodies as thefe, may float upon the Water.

80. From hence, *viz.* that the Body dipped in the Water will be *moiftned*, or not *moiftned*, it follows, that the Water will *rife up* on the Sides of fome Bodies higher than it is any where elfe, or that it will be *depreffed* lower; The Reafon of the Firft is, becaufe the Air which moves from one Side of the Veffel to the other, and paffes over the Body, permits the Liquor to rife in that Hollow which the Air cannot without great Difficulty turn into: Whereas when it paffes under, as in the Second Cafe, it depreffes the Liquor all round. And of this a Multitude of Experiments may be made, and an infinite Number of them are made without any Notice being taken of them; for every time we dip our Pen into the Ink, we may obferve, that if it be moiftned, the Ink will

80. Why Liquors fometimes rife up on the Sides of fome Bodies that are dipped in them a little way.

rise; and on the contrary, that the Ink is depressed about the Pen if it is not moist.

81. Why the Water will rise considerably in the Part where two Pieces of Glass are fitted to each other, when they are dipped a little into it.

81. If two plain Bodies which the Water will wet, such as two Pieces of clean Glass, be put very near one another, and dipped a little way into a Vessel of Water; [1] the Air which moves from one Side of the Vessel to the other, in order to get over the Obstacle that lies in its way, ought rather to pass over the Top of the two Glasses, than to descend into that streight Place which is between them: So that the Water is not so much pressed here as it is in other Places, where the Air can go without bending its Course so much, and so it ought to rise to a considerable Height above the Level of the Water contained in the Vessel; and thus we see by Experience that it does.

82. Why the Water is seen to rise of it self in small Glass Tubes.

82. And there is no doubt but that the Water would rise still higher, if the two Pieces of Glass were closed on both Sides, for by that means almost all the Air which moves cross, without bending its Course, would be hindred from entring in. Or, which is the same Thing, we may take a very small Glass Tube open at both Ends, and dip it in the Water, for then the Air cannot enter in by the Sides: so that the Water must rise very high in such sort of Tubes, if they be very slender: And indeed I have made the Water rise a Foot high in a Glass Tube so small, that one could scarce get a Horse-hair into it.

83. Why it does not rise on without End.

83. However, we must not conclude from hence, that it ought to rise on without End in these small Tubes; for it is easy to see, that the Water must stop, when the Weight of that which is risen, tends downwards with greater Force than the Pressure of the external Air has to thrust it up.

84. That a greater Quantity of Water ought to rise in an inclined Tube.

84. If the Tube be inclined, a greater Quantity of Water will get in, because, being some way supported by the Glass, it does not tend downwards with so great Force. Which is confirmed by Experience, according to the most exact Laws of Mechanicks.

85. Why the Water rises sometimes higher in the smaller, than in the larger Arm of one inverted Syphon. Tab. I. Fig. 4.

85. Having now explained the Force of the Air as a Liquid to impel Bodies which are close to it, we may say with more Assurance and Certainty than we could before, what the Situation of a Liquor in an inverted Syphon, whose Branches are of an unequal Thickness, as is here represented, will be. For Example, if we consider only its Weight, we may confidently affirm, that

[1] *The Air which moves*) See the Notes on *Art.* 85, *of this Chap.*

if

if the Water in the larger Branch, reaches up to the Height AB, it ought to riſe to the Height C in the little Tube, to be upon the Level with the other: But we may add, that if this Branch be ſo ſmall, [1] that the Parts of the Air cannot turn in it but with Difficulty, the Water will riſe conſiderably higher than in the larger Branch, ſo as to reach to D, according to what was now proved.

86. There are few of thoſe who enquire after *a perpetual Motion*, but when they ſee this Experiment, for want of rightly underſtanding the Cauſe of it, think they have found out ſuch a Motion. And indeed it looks at firſt Sight very probable, that if we take one of theſe Syphons, in the ſmaller Branch of which the Water riſes very high, and bend this Branch a little lower than the Height which the Water riſes to, it might be ſo ordered, that the Liquor with which it is filled might run out into the larger Branch, in order to riſe up again in the ſmaller one, and ſo produce a perpetual Motion: But it is certain, that [2] they are deceived who make this Conjecture; for beſides that, the Branch of the Syphon out of which the Water is to run, ought to be longer than the other, (which is not ſo here, where the bent Branch is in the Room of a whole Syphon) it is eaſy to ſee, that the Water, the Moment it endeavours to come out at the End of this ſmall crooked Branch, is more expoſed to the Force of the Air, than that which is contained in the larger Branch; whence it follows, that its Paſſage out muſt be ſtopped. *86. An imaginary perpetual Motion.*

87. This will appear more evident, if we conſider, that when the End of the ſmall Tube of a bent Syphon, whoſe Height does not exceed that, to which the Water will commonly riſe, be dipped into the Water, it will immediately be filled; but if the End of the longer Branch *87. That in a Syphon the Tube of which is very ſmall, the Water will not always run out through the longer Branch.*

1. *The Parts of the Air*) It looks very probable, at firſt Sight, as if the ſtiff Particles of the Air, either paſſed over the Mouth of the little Tube CD; or elſe ſticking in it, like little Pieces of Wood a-croſs it, ſupported the Column of incumbent Air, ſo as it ſhould not preſs upon the Water under it, with its uſual Weight: But by often repeated Experiments, it is found, that the Water will riſe as high in ſmall Tubes, though the groſs Air be exhauſted. See *The Exper. of the Academ. del Cimento, p. 55.* It is evident therefore, that all theſe Phænomena's are to be aſcribed to Attraction. See *the Notes above on Art. 69.*

2. *They are deceiv'd*) It is manifeſt, from Calculation upon Mechanick Principles, that all Queſtions about *a perpetual Motion* end in this. To find out a Weight heavier than it ſelf, or an elaſtick Force ſtronger than it ſelf. Which is abſurd.

be not depreffed lower than ufual beneath the Level of the Water in the Veffel, it will not run out into the Air, as it ordinarily does; whence we fee, that the Air pufhes it back with greater Force than it has to come out.

88. *A curious Experiment of the Preffure of the Air.* 88. For a further Confirmation of a Thing which has been fufficiently proved, I may add; that fo far is the Water from coming eafily out at the End of a fmall Tube, that fometimes it will be forced to enter and afcend into it, when it was entirely without before: Which may be tried, by holding a very clean fmall Tube open at both Ends perpendicular, and putting a Drop of Water upon the external Superficies, which may entirely ftop the Hole at the lower End, when it is got down thither; for then you will with pleafure fee the Tube filled in the fame manner as if the End of it was dipped in a Veffel of Water.

89. *What the Caufe of Filtration is.* 89. After what has been faid in the foregoing Articles, it is eafy to underftand what is the Caufe of the *Filtration* of the Chymifts: For the Piece of Woollen Cloth which they put upon the Side of the Veffel, in fuch a manner, as that one End of it is dipped into the Liquor, and the other End hangs down on the Outfide lower in the Air, refembles a bent Tube, in which the Water runs as in a Glafs-Tube: And it matters not, if this Cloth or Woollen Tube be full of Holes on all Sides, for the Air which moves round it, preffes in the Water which endeavours to come out at them, fo that it is like one continued Covering.

90. *That the Forms of hard and liquid Bodies as fuch, are not fubftantial Forms.* 90. Since our Thoughts, or if you will, our Conjectures concerning *hard* and *liquid Bodies* are confirmed by fo many Experiments, I think it fuperfluous to add any Thing more. Wherefore I fhall finifh this Chapter, with only remarking two Things: The Firft is, That if *Hardnefs* and *Liquidnefs* confift in Reft and Motion, which have their Dependence upon fomething elfe; then thefe Forms are not *Subftantial*, but only *Qualities* or *Modes* of Exiftence in the Bodies to which they belong.

91. *What Drynefs and Moiftnefs is.* 91. Secondly, That having explained the Nature of *Hardnefs* and *Softnefs*, I have at the fame time explained wherein *Drynefs* and *Moiftnefs* confift. This is evident, if we underftand the Word *Dry* and *Moift* in the Senfe of the Antients, who did not diftinguifh them from *hard* and *liquid*: As we may fee from hence, that fpeaking of *Moift*, they ufe the fame *Greek* Word as all Interpreters render *humid* or *liquid* indifferently. It appears further, that

that I have explained what the Nature of *Dryneſs* and *Moiſtneſs* is, according to that Senſe which we now uſe thoſe Words in; becauſe by *Dry*, we underſtand that which will not wet any Thing; and by *Moiſt*, that which will wet a Thing, which are two Properties which have been fully and expreſsly handled above.

CHAP. XXIII.

Of Heat and Cold.

1. That the Words, Heat, and Cold, have two different Meanings.

THESE Two Words have each of them two different Meanings: For Firſt, by *Heat and Cold*, we underſtand *two particular Senſations in us*, which in ſome Meaſure reſemble thoſe, which we call Pain and Pleaſure; ſuch as we feel, when we touch Ice, or when we go near a Fire. Secondly, by *Heat and Cold*, we underſtand alſo the Power which Bodies have to raiſe the forementioned Senſations in us.

2. In what Senſe it is, that we propoſe to treat of Heat and Cold.

2. I think we cannot underſtand what *Heat* and *Cold*, in the former Senſe of the Words, is, but only by Experience; wherefore our Curioſity will be ſatisfied, and our Pains imployed only in enquiring what that Power conſiſts in, which certain Bodies have to *warm* us, and alſo what the Power conſiſts in, which we obſerve other Bodies have to *cool* us.

3. How Ariſtotle deſcribes Heat and Cold.

3. *Ariſtotle* ſays, that *Heat* is that which collects together homogeneous Things, or Things of the ſame Nature, and diſſipates heterogeneous Things, or Things of a different Nature; and *Cold*, he ſays, is that which collects together, Things homogeneous and heterogeneous indifferently. The common Inſtances made uſe of to prove this, are *Fire*; by the *Heat* of which, a great many Parts of Gold may be collected into one Maſs, or two or more Metals which are mixed together, may be ſeparated: And *Ice*, which by its *Coldneſs*, unites together, Water, Stones, Wood, Straw, ſo as to compoſe one Body of all theſe together.

4. That Heat collects together Things of a different Nature, as well as thoſe of the ſame Nature.

4. But it is to be obſerved, that the Inſtance here given, is ſometimes faulty; for if a Maſs, compoſed of Gold, Silver, and Copper, be put upon the Fire in a Crucible, it is not true, that theſe Metals will always clear themſelves of each other, ſo as to be ſeparated and placed in their

their proper Order, one upon another, according to their different Weight. On the contrary, if feveral diftinct Pieces of Gold, Silver, and Copper be put together into a Crucible, the Fire will not fail to mix them all together.

5. That the Property of Fire, is rather to diffipate than to collect together.

5. It is true, that if the Fire acts a very long time upon a Mafs, compofed of Gold, Silver and Copper; the Silver and Copper will go all away in Smoak, and fo leave the Gold alone in the Crucible. But we ought not for this Reafon to fay, that the *Fire has a Property* of collecting Things together, becaufe this perhaps is only accidental, that is to fay, by diffipating the Firft, which refifts its Force lefs, the Gold remains alone, or laft, becaufe it refifts its Force more. In the fame manner, as if Saw-Duft, and the Filings of Lead were mixed together in a Plate, we can with our Mouths blow away the Saw-Duft, and leave the Lead-Filings alone in the Plate. For it is evident, that it is only the Refiftance of the Pieces of Gold, which is the Caufe of that Metal's being thus feparated from the Silver or Copper. For if it be left after this upon the Fire, it will continually diminifh by little and little, till it intirely vanifhes, as Refiners have tried; and this is what they mean when they fay, there is no Gold of 24 Carats, that is, none that can be refined fo pure.

6 That Ariftotle has only faid what Heat and Cold do, but not what they are.

6. But if it was true, that Heat always collected together homogeneous Things, and diffipated heterogeneous ones, and that Cold collected together all fort of Bodies indifferently, this would indeed teach us *what* Heat and Cold *do*, but not at all tell us *what they are*: But *Ariftotle* has been excufed in this, by faying, that in defining Heat and Cold as he has done, he did not fo much follow his own Opinion, as that of others.

7. What the Opinion of his Interpreters concerning Heat and Cold is.

7. I don't know whether his Interpreters have hit right, when they pretend, that his Opinion was; *that Heat, in the Fire*, for Inftance, is fomething in the Fire like that Senfation which is raifed in us, when we approach the Fire. And fo likewife, that *Cold* in Ice, is fomething in Ice very like that Senfation in us, which arifes from touching it. [1] Becaufe in his II. Book *of the Soul*, Chap. xii. after he had fhown that *Senfation* is a *Paffion*, he fays, that the Moment any Senfation is rais'd in us, we become like the Object that raifes it.

1. *Becaufe in his* II. *Book*) This Place is not in that Chapter, but in the vth Chap. of the fame Book, he fays, πάσχει μὲν γὰρ τὸ ἀνόμοιον ὄν, πεπονθὸς δ' ὅμοιόν ἐστιν.

8. But

8. But whether *Aristotle* were of this Opinion or no, thus much is certain, that they have no Proof of what they affirm; for it is no Proof to say as they do, that the Fire cannot give that which it has not; because taking the Word *give*, in the Sense here used, there is no doubt but that the Needle, when it pricks us, *gives* us Pain, and yet there is no reason to believe from hence, that the Needle has in it any Pain like that which it causes in us. *8. That they have no Foundation for their Opinion.*

9. Farther, the Heat of the Fire, and the Cold of Ice being Properties or Qualities belonging to Bodies which every one acknowledges to be inanimate, they cannot be like the Sensations which we feel by their Means, because these Sensations belong to us as animate Creatures. And because the same Thing may sometimes happen to raise in us two different Sensations at the same time, it will follow from their Opinion, that the same Thing may be hot and cold at the same time, which is impossible; yet the Air which we breathe out of our Mouths, may at the same time feel hot or cold according as it is differently applied to our Hands in blowing upon them. *9. That it is absolutely false.*

10. By reflecting upon this Experiment, which shows us, that the same Air feels hot or cold, not only from its being applied in a different manner to our Hands, but also from the different manner of making it come out of our Mouths; it is easy to conjecture, that the *Heat* of a Body consists in a peculiar Motion of its Particles. And because the nearer we put our Lips together, and make the Air come out quicker and stronger, the less we feel the Heat; hence we conclude, that the Heat of a Body does not consist in the direct Motion of its Parts. Now whatever is in Motion, either moves on directly, or else has an unequal and irregular Motion, as it were about its own Center; from whence we may infer, that the Air which comes out of our Mouth, besides that direct Motion, by which the Whole of it is removed from one Place to another, it has also a great many of its Particles moved round with a circular Motion about their own Centers: By which means those which are applied to our Hands, with this sort of Motion, excite in us a kind of Tickling And because it is this kind of Motion which raises in us the Sensation of Heat, we ought also to conclude, *that the Heat of Bodies consists in this Sort of Motion of their small Parts.* *10. In what the Heat of hot Bodies consists.*

11. So

11. The Resemblance there is betwixt Heat and Pain. 11. So that what is in the Object is very different from the Senſation which it raiſes. And this ought not to be thought more ſtrange, than the Difference there is betwixt the Figure and Motion of a Needle, which pricks us, and the Pain which it cauſes. For as it is evident from the Inſtance of Pain, that the Soul being united to the Body, it is the Appointment of Nature, that certain Perceptions of the Soul ſhould follow from certain Motions or Diviſions which the *Needle* cauſes in the Body. So alſo we ought to think, that Nature has appointed that from that particular Manner in which our Body is moved by the Fire, there ſhould ariſe a particular Perception; and this is what we call Heat, taking it in the former Senſe of the Word.

12. That Bodies may become hot, to which it is certain, nothing has happened but Motion. 12. This is confirmed by Experience, which teaches us, that many Bodies are made capable of warming us, to which we cannot ſuſpect any Thing has happened but only Motion. It is to no purpoſe to inſtance in them all: I ſhall content my ſelf with the following Example.

13. The I. Example. 13. And, Firſt, It is certain that when *our Hands are very cold*, we find by Experience, *that if they be rubbed a little while together*, we ſhall feel a conſiderable Heat.

14. The II. Example. 14. *Secondly*, As was before obſerved, *Lime having cold Water poured upon it*, though it was before cold, will acquire ſuch a Motion of its Parts, that they will be diſunited in a ſhort time, and by that Means will become capable of heating us in ſuch a manner, that it will be very painful to hold it in one's Hand.

15. The III. Example. 15. *Rotten Dung*, that is, ſuch as diſſipates it ſelf by little and little, becomes ſo hot, as to ſerve inſtead of a moderate Fire in many Chymical Operations. And Chymiſtry furniſhes us with many other Examples not ſo common, which ought to be more known to the World than they are.

16. The IV. Example. 16. For Inſtance, if a few *Filings of Braſs* be thrown into a large Veſſel in which is a little *Aqua-fortis*, it will immediately raiſe ſuch a Fermentation, that the Bottle will ſeem quite full, and at the ſame time will be ſo hot that we cannot touch it without being burnt.

17. The V. Example. 17. Further, If, as was before ſaid, *Oil of Vitriol* and *Oil of Tartar* be mixed together, though ſeparately neither of them are combuſtible, they will immediately acquire an incredible Fermentation on a ſudden, and at the ſame time a very ſenſible degree of Heat.

18.

18. It is true, that in these Sort of Examples, it may with some Reason be said, there is something that we do not throughly understand, wherefore I shall stay a little, before I say what the Cause of these surprizing Motions may be: To come therefore to some more familiar Instances; we observe, *that two hard Bodies rubbed against one another*, do so agitate the Parts of each other, as not only to burn us when we touch them, but their Motion will increase to such a Degree, as to set each other on Fire. Thus in very dry Weather, the *Wheel* and the *Axle-Tree* of a Chariot, when it goes very quick, and in general, all Sorts of Engines which are made of Matter that will burn, and which move very quick, are apt to take Fire. Nothing is more common, than to see a *Wimble* grow hot in boring a Hole in a hard thick Piece of Wood. So likewise, if we *file* or *sharp* a Piece of Iron or Steel, it will grow so hot sometimes as to lose its Temper. And a *Saw*, which the Wood will not easily yield to, acquires a very notable Heat. But nothing sooner takes Fire than a small Piece of *Flint* or of *Steel*, which is struck off, and put into a violent Motion by striking these two against each other. Now in all these Instances, there is nothing added to these Bodies but Motion. *18. The VI. Example.*

19. All the Antients who have considered the greatest Part of these Experiments, have asserted that *Motion* is the *Principle of Heat*; which I acknowledge with them to be true; if by *Motion* they mean *the Motion of the whole Bodies*, which is the Cause of the two Bodies rubbing against each other; but if by *Motion* they mean *the Motion of their insensible Parts*, I think they have not said enough: For the *Motion* of these Parts, is *the very Heat it self* of those Bodies. *19. An Explication of the Opinion of the Antients concerning Heat.*

20. I see no Objection that can be made against this: For when they object, in order to show, that Motion is not [1] the Principle or Cause of Heat, that a Ball out of a Cannon which moves very quick, does not burn the Wood which it enters into; or that a Musket Bullet does not burn the Wood which it penetrates, though it be very dry; this contradicts the Opinion of those only who pretend that Heat consists in the Swiftness of the Motion of all sorts of Bodies how gross soever. But this Objection makes nothing against us, who affirm, that Heat consists in the different and violent Agitation of the insensible *20. Why a Cannon Ball which moves very quick, does not grow hot nor burn.*

1. *The Principle or Cause of Heat*) Is not the Heat it self.

Parts

Parts of Bodies. But when a great Bullet moves very quick, its Parts may be at reſt with reſpect to each other, and therefore it is no wonder that they don't burn the Bodies which they touch.

21. *Why the Nave of a Wheel grows hot, and not the Fellows.* 21. If we reflect upon what has been ſaid, we ſhall not at all wonder, that the Bands of Iron which are about a Wheel do not grow hot as it does in the Middle; for though they deſcribe larger Spaces by their Motion, yet notwithſtanding this, their Parts are not agitated with reſpect to each other, as thoſe in the Middle are, which continually rub againſt the Axle-Tree.

22. *Why a Piece of Iron when filed, grows hot, but not the File.* 22. We may very eaſily anſwer a great many Queſtions which may be put to us by thoſe who will not allow, that the Form of a hot Body conſiſts only in the Motion of its ſmalleſt Parts: Thus when they ask, how it is poſſible, that when a Piece of Iron fixed in a Vice, is filed, the *Iron* grows conſiderably hot, but the *File* which moves upon it is ſcarce warm at all: It is eaſy to anſwer, that the Parts of the File moving upon the Iron, and continually grating it, not only with its own Parts, but alſo with ſome of the Parts of the Iron which it has rubbed off, and which remain ſometime between its Teeth, muſt neceſſarily excite a very great Agitation of the Parts of the Iron which is filed, and conſequently heat it very ſenſibly. But this is not the Caſe of the File; for though its Parts are grated as much as thoſe of the Iron, yet becauſe it is longer, the ſame Teeth do not twice together touch the Body which it grates, but there is always ſome ſmall diſtance of Time, between the two Rubs of the Parts of the File; during which time, that Place which may have begun to acquire ſome ſmall Heat, may loſe it again.

23. *Why Iron when it is filed grows hotter than other Metals.* 23. There are ſo many Things to be conſidered in this Experiment, that a ſmall Difference alters all the Circumſtances. Whence it is, that a Piece of Copper or Lead, when it is filed, ought not to grow ſo hot as Iron, both becauſe Copper and Lead are not ſo ſtiff, and becauſe it is eaſier to ſeparate their Parts than the Parts of Iron; ſo that the File being never applied twice together to the ſame Part of the Body which it grates, it cannot ſhake its Particles ſo much: And this is ſo true, that if we try to file a Piece of Copper, with an old worn File, which will ſhave off but a little at a time, the Heat will be as great as that produced in the Iron.

24. Now

24. Now if any one asks, why, in ſawing a Plank of Wood, the *Saw* grows hot and not the *Wood:* I anſwer, that the Plate of the Saw, ſticking in the Slit of the Wood, and being rubbed againſt each Side, the Parts of it muſt be ſenſibly ſhaken: Whereas it is evident, that the Plank ought not to grow hot in the Place againſt which the Teeth of the Saw go, for the Reaſon juſt now given, *viz.* becauſe it cuts the Parts off; neither ought it to grow hot on the Sides, eſpecially if the Wood be eaſy to ſaw, becauſe the Saw advances further and further into the Slit, and ſo does ſcarce twice together touch the ſame Part of the Wood.

24. Why a Saw grows hot, and not the Wood.

25. It is true, that if the Wood be very hard, and difficult to ſaw, and if the Saw ſticks in the Slit which it makes, the Plank will then become pretty hot; but we ſhall not be able to perceive it by our Touch, becauſe the Parts of the Wood being large, loſe their Motion in a Moment, and it will take ſome time to pull out the Saw, and to open the Slit ſo wide as to put our Hand in to feel. But though we cannot perceive it by our Touch, we may ſee it with our Eyes; for the Places againſt which the Saw for ſome time grated look burnt, as if they had been in the Fire. And it happened ſome time ago, that deſignedly ſawing a Piece of hard Wood, fixed in a Vice, in a Smith's Shop, with a Saw which ſtuck in the Slit it made, I at firſt perceived a Smell like burnt Wood, and continuing to ſaw the Wood with greater Force, ſeveral Sparks came out of it.

25. How the Wood when ſawn may grow hot.

26. The Experiment which ſeems to be the moſt contrary to the Principle we have laid down, is, that if we drive with a Hammer a large Nail into a piece of hard Wood, we ſhall not find it grow warm while it is driving in, but after it is in, and the Hammer does nothing elſe but beat the Head flat, then it will begin to acquire ſome Heat: Yet is there nothing in this, but what perfectly agrees with our Notion of Heat. For as we make it to conſiſt wholly in the Agitation of the ſmall Parts of the Body; it is certain, that the Nail ought not to grow hot, when it is moved all together in entring into the Piece of Wood; but that it ought then to begin to grow hot, when it ceaſes to move ſo, and its Head begins to be made flat; for it is then only that the ſmall Parts begin to be in Motion, and acquire an Agitation ſufficient to Heat. And indeed, when the Head of a Nail is made flat, all that is done, is, that there are by that Means fewer Parts placed one upon another, and more by each

26. Why a Nail driven into a Piece of Wood with a Hammer does not grow hot.

other's Sides; which cannot be, but by the Motion and Agitation of these Parts, which by their beating against each other, cause that trembling in which Heat consists.

27. *That Flame ought to be very hot.* 27. Having thus endeavoured to answer the Objections that might be made against us; we come now to draw some Consquences from what we have laid down; because if these agree with Experience, they will help to confirm us in this, that we are not far from the Truth. In the first Place then, let us consider, that seeing Heat consists in a certain Motion, or a certain Agitation of the small Parts of a Body; it is certain, that the more the Parts of the Body are thus moved or agitated, the greater will the Heat be. Now it is evident, that [1] *Flame* is more agitated than any other Body which comes under our Senses. For, for Example, it is this violent Agitation of the Parts of the Wood which nourish the Flame, that makes the greatest Part of them fly away, and that of all the Wood that can be burnt in a Day, so very little remains in Ashes; which we do not find in the forementioned Instances, where there is only a mod[illegible]te trembling of the Parts of the Bodies which is not sufficient to disunite them entirely. And this is the Reason why *Flame* ought to be the hottest Thing in the World, as every Body knows it is.

28. *How a Body that is not so much agitated as Flame may yet be hotter.* 28. However, this must be understood with some Restriction, that is, if they agree in all other Particulars; for it is not inconsistent herewith, that there should be some Bodies hotter, and more capable of heating than Flame, if they consist of more solid Particles, and consequently such as are more capable of Agitation; wherefore *Iron*, tho' it be not red hot, will burn more, if we touch it, than the *Flame of Straw, or Spirit of Wine* will do.

29. *Why Sea-Coal will burn more than any other.* 29. The Difference that there is betwixt the Grossness of the Particles into which the Bodies that are burnt are resolved, is the Cause of so much Difference in the *Flames*. Thus, *Oak* being more solid than *Straw*, but not so solid as *Sea-Coal*; their *Flames* are also proportionably more or less burning or strong one than another: And the Use that *Smiths* make of them, according as they have occasion, shows plainly, that *Sea-Coal*, acts more strongly than all other, because when they would heat a

[1]. *Flame is more agitated*) Concerning the Nature of Flame and Fire, See *Part the* IIId. *and the whole* ix. *Chap. with the Notes.*

Piece

Piece of Iron very much, they prefer this Coal to all others.

30. When a Body melts, and liquifies, as I may call it, by little and little into Flame, it is impoffible but that the Particles which flip and rub one againft another, muft be diminifhed and broken into a thoufand Pieces, and fo make a very fine Duft, which, that it may continue to move with that violent Agitation which it has acquired, gets off from that Mafs of which it was before a Part, and flies into the Air; which is what we call exhaling or evaporating: And hence it is, that the Fire has the property of *diminifhing* all Bodies which it acts upon.

30. How Heat deals with Bodies, and diminifhes the Bulk of them.

31. This being allowed, there is no Difficulty in refolving that Queftion commonly asked, *viz.* How it is poffible that Heat fhould produce at the fame time two feemingly contrary Effects: Such as *hardning of Clay*, and *foftning of Wax*. In order to this, we need only obferve, that Clay is compofed of two Things that are very different from each other, *viz.* Earth and Water; the Latter of which may very eafily be evaporated, before the Particles of the Former are confiderably fhaken; and fince the Clay is foft for no other Reafon, but becaufe the Particles of the Water are in fome fort of Agitation, amongft the Particles of the Earth, to which they belong; it muft needs be, that when the Water is all evaporated, and the Particles of the Earth remain alone, they will reft againft each other, by their own Weight, and fo by that means compofe a hard Body. On the contrary, the *Parts* of Wax are pretty near equal; fo that the groffer Particles are agitated before any confiderable Quantity of the fmaller ones can fly away. And therefore all the Particles of a Piece of Wax being a little in Motion at the fame time, compofe together a foft Body.

31. Why Heat hardens Clay and foftens Wax.

32. It may be obferved alfo, that the *Heat* muft be but moderate, to *harden Bodies*: For if it be very violent, it will make them *liquid*. And thus we fee, that Flame melts not only Metals, but alfo Afhes, Sand, Stones, and Flints, of a Compofition of which all Sorts of Glafs are made.

32. That the Heat needs not be very great, to harden Bodies.

33. From the different Degrees of Heat, and the various Texture of the Parts of which a Body is compofed, we may conclude, that very different Effects will be produced: For firft; If a Body, *whofe Particles are very clofe to one another*, be confiderably hot, whatever the

33. How Heat rarifies fome Bodies.

Figure

Figure of these Particles be, so they be not exactly round, when they are agitated or turned round their Centers, their angular Points, or the Parts which are most distant from the Center, must necessarily meet one another, and turn one another out of the Way; whence it follows, that the Heat will cause a Rarefaction in this Body, as we see in Milk, and all other Liquors; and also in most hard Bodies, in which few or none of their Particles fly off when they are hot: Thus red-hot Iron is something bigger than when it is cold.

34. How it condenses others. 34. But if *the Particles of a Body be very smooth, and easy to be put in Motion, and yet are so placed with respect to each other, as scarce to touch one another, so that the Composition is very rare*; a very little Heat coming upon it, and shaking the Particles, may cause them to approach nearer one another, and *the whole Body* may be by this means *condensed*. And thus we experience, that Heat when it melts Snow, reduces it into a less compass.

35. Why Water, when it is very near freezing, is rarer than when it is not so cold. 35. And because the Particles of almost all liquid Bodies must every Moment bend themselves, or some way alter their Figure, in order whereunto, they must be moved with sufficient Force; therefore if the Heat, or that which forces them to move, or so agitates them as to make them Liquid as usual, does almost wholly cease, all that the Particles can do, with that little which they have remaining, will be to move themselves without bending so much as is necessary to join them together: And then the Liquor will be rarified a little, and after it is so rarified, the Addition of the least degree of Heat, will cause its Parts to approach nearer one another again. Thus *Water is a little rarified before it freezes*, and is condensed again by the least Heat that can be. But because some Skill and Pains is requisite to prove this by Experience; I will set down the Means I made use of to make it appear sensibly.

36. An Experiment to show that Water, when it is extremely cold, is rarified. Tab. III. Fig. 19. 36. I caused a Glass Vessel to be made like that in the Figure, the largest Mouth of which is at A, and the other at B, the End of the small Tube BC, which is very slender: I poured Water into the Hole A, 'till the Vessel was full, and consequently 'till it arose up to D, in the small Tube, then I stopped up the Mouth A close with soft Wax, and a Hog's-Bladder tied on: Having thus prepared it, if the Heat of the Air be so diminished that

that the Water be very near freezing, * it will fwell, and rife up to the Mouth B, where it will fometimes run over a little: Then, if we put our Hands or any other Thing that is warm, to the Veffel, we fhall fee the Water condenfe it felf, and fink in the fmall Tube almoft down to the Bottom C. It is true indeed, that if we continue to heat the Veffel, the Water contained in it, will begin to dilate itfelf again, the Reafon of which, is that which I have now given.

37. That the Quantity of Heat, may be determined by the Rarefaction of the Air.

37. Becaufe we can move our felves with greater Eafe in the Air than in the Water, this is a Proof that the Parts of the Air are much finer than thofe of Water. Wherefore the leaft Heat that can be, muft dilate the Air; and confequently, *The Quantity of the Rarefaction of the Air, will very exactly fhow the Quantity of Heat here on the Earth*; that is to fay, we can judge that it is hotter, one Day of the Year than another, by obferving in which of thefe two Days, the Rarefaction of the Air is greateft.

38. A Defcription of a Thermometer. Tab. IV. Fig. 1.

38. Now in order to make this Rarefaction fenfible, there has been invented in our Days an Inftrument called a *Thermometer*, pretty like that in the Figure: DF is a very fmall Tube of Glafs about two Foot long, like a Neck belonging to the Bottle A, which is Glafs alfo, and about as big as a Tennis-Ball. The lower End is bent and made large, fo as to form another Bottle marked F, which needs not be fo big as the Bottle A, and has a fmall Hole made in it at B.

39. The Manner of preparing, and the Ufe of the Thermometer.

39. The *Thermometer* is at firft entirely empty, that is, full of Air only, part of which is forced out, by heating the Bottle A, at the fame Time that the other Bottle F is dipped into a Veffel of *Aqua-fortis*, tinctured of a Green Colour, by diffolving a Piece of Copper in it. We choofe *Aqua-fortis* rather than common Water, becaufe it is not fo fubject to freeze, and does not fo eafily evaporate. As the Air remaining in the *Thermometer* grows cool, it has not Force enough to preferve that Bulk which it had before, and fo is obliged to retire up into the Glafs, and leave Room for the *Aqua-fortis*, which by its own

* *It will fwell*) Becaufe its Parts are made ftiff, by the Mixture of *Nitrous* Particles, and of other Salts. (*See the Notes on Art.* 54.) However it muft be acknowledged, that fomething ought to be allowed for the Contraction of the Glafs. For as Heat by encreafing the Motion of the Parts, dilates and extends Glafs and other Bodies, fo cold by ftopping the Motion of their Parts contracts and condenfes Glafs and other Bodies. *See the Experiments of the Acad. del Cimento, p.* 109, *&c.* The Water therefore a little before it freezes, rifes in the Tube CB, partly becaufe it is a little rarified, aod partly becaufe the Glafs AC is a little condenfed by the Cold. Tab. III. Fig. 10.

M Weight,

Weight, affifted by that of the external Air, gets into the Bottle F, and from thence rifes up in the Tube towards C. After this, the Inftrument is taken out of the Veffel in which it was dipped, and without doing any Thing more than fixing it in a Wooden Frame, marked with feveral Divifions, it fhows how much hotter it is at one time than another.

Tab. IV. Fig. 1.

40. The Reafon of this Ufe.

40. For the more the Green Liquor is forced to defcend by the Rarefaction of the Air in the upper Part of the Tube, the hotter it is in the Place where the *Thermometer* is fixed: And on the contrary, it is a Sign of greater Cold, when this Liquor rifes higher, becaufe this fhows that the fame Air has not Force fufficient to preferve its Bulk, but is obliged to give way to the *Aqua-fortis*, which the Weight of the external Air that preffes upon the Hole B, continually forces to rife up as high as it can in the Tube DF.

41. That this Thermometer does not exactly diftinguifh all the Differences of the Heat.

41. However, we muft take care not to be deceived in the Judgement we make of the Heat, by barely looking on the *Thermometer*; becaufe the Weight of the Air being not always equal, it may be, that the Air will prefs more upon the Liquor contained in the Bottle F, at fome Times than at others, and confequently force it to rife higher in the Tube FD, and may occafion us to think that it is colder than it was before; When perhaps the Heat of the Air was neither greater nor lefs.

42. A Defcription of another Thermometer.

Tab. IV. Fig. 2.

42. This occafioned the making another Sort of *Thermometer* not long fince, which has but one Bottle of Glafs only, and has a long flender Neck as is here reprefented. At the Hole A is put in as much Spirits of Wine as will fill the Bottle quite full, and the Neck alfo as high as the Place marked B, and then putting the End A into the Flame of a common Lamp fuch as Workmen ufe, ftop up the Mouth there, and then the Thermometer is finifhed.

43. Why the Heat condenfes the Air in this Thermometer.

Tab. IV. Fig. 2.

43. When the Heat of the Air increafes, the Spirits of Wine dilate and rife above B, and fo force the Air in the Part of the Neck BA to condenfe. Which it may eafily do, becaufe when it was inclofed here, it was very much dilated by the Flame which melted the Glafs, in order to ftop the Hole A. On the contrary, when the Weather grows cold, the Spirits of Wine contract into a lefs compafs, and defcend below the Place marked B, and permit the Air to extend it felf beyond its Limits. By this *Thermometer* therefore we judge whether it be more or lefs hot, by the rifing and falling of the Spirits of Wine; and we need not fear the

the Inequality of the Weight of the Air, becauſe it cannot get in, to make any Alteration in our Obſervations.

44. Though the Fault in the foregoing *Thermometer* is remedied in this, yet has this another of as ill Conſequence, *viz.* That becauſe the Spirits of Wine dilate and condenſe but very ſlowly, we cannot ſoon enough perceive the Alteration that is made in the Heat or Coldneſs of the Air. And there is another Fault ſtill, (if it be not made larger than they uſually are) which is, that the Spirits of Wine, being not capable of a very great Rarefaction, its Riſing and Falling in the Neck of the Bottle will not be of ſo great Length, as to diſtinguiſh the ſmall Changes that happen in the Heat of the Air. But one Remedy of this, is, as I ſaid, 1 to make the *Thermometer* very large. I have one in which the Difference betwixt the greateſt and leaſt Height of the Spirits of Wine is above three Foot. *44. A Defect in this Thermometer.*

45. After what has been ſaid concerning Heat, there remains nothing more to be explained, but that which we experience in *Lime, when either Water is poured upon it, or it is put into Water:* And this may ſerve to explain why other hard Bodies grow hot as ſoon as certain Liquors enter into their Pores. In order to our Satiafaction in this Matter, we need only conſider, that the Stone of which Lime is made, has ſo very ſmall Pores that the Water can ſcarce enter into them; but after it is put into the Kiln, the Fire which penetrates it, carries away ſome of the internal Particles, and by that Means enlarges the Pores ſo much, that afterwards the Particles of the Water can eaſily enter, being only ſurrounded by the 2 Matter of the firſt Element: Wherefore being freed from the Matter of the Second Element, when they enter into the Pores, they can eaſily acquire all the Force of the Firſt Element in which they ſwim; ſo that moving very quick, and being alſo pretty groſs, they have Force ſufficient to diſunite the Parts of the Lime, and to carry the ſmall Duſt of it along with them: And it is principally in the Agitation of this Duſt that the Heat of the Lime conſiſts. *43. Why Lime grows hot by having Water poured upon it.*

1 *To make the Thermometer*) This Inconvenience may be remedied by bending the Neck of the Thermometer into a Spiral; for by that means the Spirits of Wine will riſe eaſier and quicker, and the Difference of the Degrees of Heat may be more eaſily obſerv'd.

2. *Matter of the Firſt Element*) See the Notes below on Art. 48.

46. How a Cock of moist Hay grows hot. 46. There is no need of wetting Hay in order to have it grow hot of it ſelf, it is ſufficient, *if it be heaped up whilſt it is green*; for every Spire of Graſs contains in it ſelf enough of the Moiſture which it ſucks out of the Earth, the Particles of which go and come out of one Spire into another, and ſwim at firſt in the Matter of the Firſt and Second Element, where conſequently they have only the Velocity of the Second Element. But afterwards when the Graſs grows dry, their Fibres ſhrink, and their Pores grow ſo ſmall, that the earthy Juice which runs out of one into another, ſwims in the Matter of the Firſt Element only, whoſe Velocity it then obeys, and ſo has a Force ſufficient to move the groſſer Parts of the Hay, and to heat them by that Means.

47. Why Hay when it is ſcattered does not heat. 47. I ſaid expreſſly, that the Hay muſt be heaped; that the Particles of the earthy Juice which come out of one Spire of Graſs may enter into another with all their Motion; becauſe if the Hay be ſcattered in the Meadow, the Juice which comes out of the Spires of Graſs, is diſſipated in the Air; and does not enter again into others, to cauſe that Agitation which is neceſſary to produce Heat.

48. How two Liquors that are cold, grow hot when mixed together. 48. As to the Heat which ariſes from the Mixture of two different Liquors, we need only imagine 1 that their Particles are of ſuch a Figure, that they can more cloſely unite when they are mixed together, than when they are ſeparate,

1. *That their Particles*) Since there is no ſuch thing as this *Firſt Element*, by all theſe Experiments, *it appears, that in Fermentations, the Particles of Bodies, which almoſt reſt, are put into new Motions by a very potent Principle* (namely Attraction) *which acts upon them only when they approach one another; and cauſes them to meet and claſh with great Violence, and to grow hot with the Motion.* Newt. Opt. pag. 355. But becauſe Heat does not conſiſt in every Motion, but in a peculiar Motion (and of certain Particles perhaps) of the ſmall Particles of all Bodies; if the Fermentation or Ebullition ariſes from the Mixture of ſuch Sort of Salts as produce Cold. (*See the Notes on Art. 54. below*) the Fermentation may not only be attended with no Heat, but with a ſenſible Cold. Thus *Salt-petre* mixed with *Spirit of Vitriol* or other *acid Spirits*; alſo *volatile Salt of Urine* with *diſtilled Vinegar* or *Spirit of Vitriol*; alſo *Sal Armoniac* and *Corroſive Sublimate* reduced to a Powder ſeparately, and then mixed together; if *diſtilled Vinegar* be poured upon them, they will be very cold during the Fermentation. (See *the Philoſoph. Tranſactions* N°. 274.) Alſo Sal Armoniac mixed with a double Quantity of Oil of Vitriol will bubble up and ſwell very much, and yet the Liquor at the ſame time feel very cold. See *the Exper. of the Acad. del Cimento, p.* 153. Nay further, from the Motion of ſome Salts which are naturally in all Water, it is, that Water it ſelf incloſed in a Glaſs, and put into a larger Veſſel full of Water, if red-hot Coals be thrown into the Water in this larger Veſſel, will firſt grow cold (as appears by applying a Thermometer to it) before it receives the Heat communicated by the Water which ſurrounds it.

ſeparate; and when they are ſo mixed, they ſwim in the Matter of the firſt Element only, at leaſt, during that little Time we ſee them ferment: Which is confirmed from hence, that after the Fermentation ceaſes, we find many Particles united together, and that they compoſe a great many ſmall hard Bodies.

49. Having thus explained the Form of a *hot Body*, it will be eaſy to determine that of a *cold Body*, which is the direct contrary: For if we conſider, that *Cold* extinguiſhes, or rather diminiſhes Heat, there will be no Doubt, but that thoſe are *cold Bodies*, which cauſe that particular Motion in which Heat conſiſts to ceaſe: Now we know that this Property belongs to three Sorts of Bodies: Firſt, to ſuch as have their Particles at Reſt with reſpect to each other. Secondly, to ſuch whoſe Particles may be in ſome Agitation, but leſs than thoſe of the hot Body to which they are applied; and Laſtly, Such whoſe Particles may be ſufficiently agitated with a Motion proper to excite in us the Senſation of Heat, but is attended with a different *Determination* which changes and ſtops the Motion which the Parts of our Body are in, and therefore cool it. The whole Difficulty therefore is, whether *Cold* conſiſts in one of theſe Modes only, or in each of the Three. *49. How to find out the Nature of Cold.*

50. Now ſince there are Three Sorts of cold Bodies, we may affirm, that *Cold* conſiſts in each of theſe three Modes. For, Firſt, The *Cold* which is common to all hard Bodies, cannot conſiſt in any Thing but what is common to them all, *viz.* in the Reſt of their Particles: Further, the *Cold* which we feel in Summer-time, when we go into the Water, eſpecially when we are up to the Middle, ariſes from hence, that the Particles of the Water having leſs Motion, than our Bodies have in all thoſe Parts which are near the Heart, they receive ſome Motion from us, and at the ſame time we loſe it. And of this we have a very convincing Proof, becauſe the ſame Water feels many times warm when we dip our Hands into it, becauſe they are not ſo hot as our Breaſt. Laſtly, It is evident, that the Breath which comes out of our Mouths, when we contract our Lips, or the Air which we put into Motion with a Fan, in the Heat of Summer, ought to cool us; if we conſider that the direct Motion of them diminiſhes or alters *a little* the Determination and Agitation of that Motion which is in the Part of the Body where we feel it cool. *50. That there are three Sorts of cold Bodies.*

51. Why a cold Body, when it cools another, warms it self.

51. For a Confirmation of this, we may obferve, that cold Bodies cannot make any Alteration in the Motion of hot Bodies, without as much altering that Mode in which their own Coldnefs confifts; that is, *a cold Body cannot cool another, without growing warm it felf*, and fo we find by Experience.

52. Why fome Bodies are colder than others.

52. We may obferve further, that the more Particles a cold Body has at Reft, the more thofe of a hot Body to which they are applied, ought to lofe of their Motion, in order to communicate fome of their Heat to the other. Thus Marble having more Particles at reft than Wood which has more Pores, and is full of a Liquid Matter which is in continual Motion, ought to feel colder than Wood.

53. Why the Air near a cold Body is colder than in other Places.

53. This alfo may ferve to explain to us, *why the Air which is near Marble, or other Bodies, which have very fmall Pores, ought not to be quite fo warm, or ought to be a little cooler, than that which is in Places where fuch Bodies are not.* For the groffer Parts of the Firft and Second Element, which cannot enter into the fmall Pores of thefe Bodies, muft neceffarily be reflected back from them; and for the moft part there is only the moft fubtil Matter about them, which is ready to enter into them, or which cannot but come out of them; and confequently this is not able to agitate the grofs Particles of the Air, which are proper to raife in us the Senfation of Heat.

54. Why Snow feels colder than Marble.

54. When I fay that Bodies which have more Particles at reft, ought to feel colder than others which have fewer, I fuppofe that the Particles of each of thefe Bodies are equally fufceptible of Motion; for if we fuppofe that the Particles of a Body are very eafily to be put in Motion, and to lofe their Reft; this Body, though very porous, ought much rather to receive within it felf the Agitation of a hot Body, and by that means cool it, than another Body which has fewer Pores and more Parts at reft, but fuch as are not fo eafie to be moved. And hence it is, that when we touch *Snow*, which is very rare, it cools us much more than when we touch *Marble*, whofe Particles are much lefs capable of being put into Motion. [1]

55. The

[1] It is much more probable that Cold (which is not merely *comparative*, as that of *fimply* Hard or Liquid Bodies is; but produces real Effects, fuch as Freezing, Breaking in Pieces, Rarefaction, &c.) is owing to fome Par- [illegible] of *Nitre* and other *Salts* which

55. The Nature of Heat and Cold being such as I have now described, if you call to mind what was before said concerning the Form of moist or liquid Bodies; it will be easy to understand how *Heat* and *Cold*, which are direct contrary Qualities, may yet, though by quite different and opposite Ways, produce one and *the same Effect*, viz. *Drying or Hardning*: As we experience in this, that the same Things, as *Clay*, for Instance, are made as *dry* by the *Cold* in the Winter, as they are by the greatest *Heat* in the Summer: In order to understand the Reason hereof, we need only consider, that the Parts of moist or liquid Bodies, such as Water, lose all their Motion when it is very cold; wherefore since such Bodies by this Means acquire the Form of hard or dry Bodies, it is not at all surprizing, that Clay which is composed of Water and Earth, should grow hard and dry, when the Weather is very cold; seeing the Water alone, to which all the Softness of the Clay is owing, freezes and grows hard. On the contrary, Heat causing the Parts of the Water, by whose Means the Matter of the First and Second Element kept the terrestrial Parts of the Clay in some sort of Motion, to evaporate; these terrestrial Particles, by their own Gravity, will be at rest with respect to each other, and by that Means compose a dry or hard Body.

55. How both Heat and Cold are drying.

56. Hence we may also see the Reason of a Maxim founded upon a Multitude of Experiments, *viz. That Heat and Moisture are Principles of Corruption.* For a Body is corrupted when there is a very remarkable Change in it, which doubtless may be effected by such a Motion as this. Now these two Qualities consist in this Motion.

56. Why Heat and Moisture are Principles of Corruption.

57. On the contrary, by Rest, the Parts of Bodies are kept in the same Situation, and Cold causes them to be at Rest; wherefore we may lay this down for a Maxim, *That Cold hinders Corruption.*

57. Why Cold hinders Corruption.

58. However we must not affirm this to be a general Maxim. For if a Body has Pores large enough to contain a good deal of Liquor, and these Pores be filled with Water; because Water cannot freeze without dilating it self, it may so happen, that in freezing it may break

58. Why a great Cold crumbles Stones.

which are of certain Figures proper to excite that Sensation, and to produce those Effects. And hence it is, that *Sal Armoniac* or *Salt-Petre*, or *Salt of Urine*, and many other *Volatile Alkalizate Salts*, make the Water with which they are mixed very cold. See above on Art. 48.

the Body, which contains it, in Pieces. And thus we see that soft Stones, which are exposed to the Frost, crumble and are reduced almost to Powder, before the Water which they have sucked in, can get out.

59. Why Frost is hurtful to Plants.

59. This perhaps is the Reason of what is said by some of the Antients, *That a hard and penetrating Frost has a Power of Burning.* However, it very often happens, that we ascribe that Effect to Frost, of which it is only a very distant Cause, and which is immediately produced by Heat. For Example, when we say, that Frost corrupts Fruits and the Buds of Plants, we ought rather to say [1] that the Heat corrupts them whilst the Frost is dissolving, because it cannot get into the Pores of the frozen Fruits, not make the internal Parts so soft as they were before they were frozen, without having first intirely destroyed the Connexion and Order of the other Parts, nor consequently without having altered the whole Composition of the Parts.

60. Why Cold does not hurt some Parts of the Plants.

60. For Proof of this we may observe, that it is the extreme Parts of the Plants, which always contain in them more Moisture than the other Parts, that are almost the only ones corrupted by the Cold, and also that the Cold does not hurt them till after they are budded; for before they bud, the Cold does not hurt them; for which we can give [2] no other Reason but this, that Plants before they put forth their Buds, are not so full of watry Juices, and their Pores are large enough to suffer the subtil Matter, to put those Parts which may have lost their Motion into Motion again, without necessarily destroying the Connexion of those it first acts upon, and which are more external, before it comes to apply it self to the other which are more internal.

61. A Confirmation of this.

61. For a Confirmation of the Truth of the *foregoing Art.* we may add, that in Northern Countries, where the Cold is so great, that a Man cannot go into the Air without running the hazard of having the extreme Parts of his Body frozen; *if their Noses or Fingers be frozen, they do not lose them, if they keep from the Fire, and rub them with handfuls of Snow.*

1. *That the Heat corrupts them*) However for the most part, the Particles of the Juice being dilated and made stiff by the Cold, break in Pieces, and spoil the tender Parts of the Buds, as is observed by Mr. *Le Clerc in his Physicks, Book* V. *Chap.* xiii. *Sect.* 65. Though this Defect does not appear till the following Heat shows it.

2. *No other Reason*) See *the Notes on the foregoing Art.*

62. Ha-

62. Having thus explained the Four principal Qualities that come under the Senſe of Feeling, *viz.* *Hardneſs*, *Liquidneſs*, *Heat*, and *Cold*; there is no Difficulty in any other which may come under the ſame Senſe, ſuch as *Rough* and *Poliſhed*. For all theſe Qualities do ſo clearly follow from the Diſpoſition of the Parts of Matter only, that there is no need of any Explication of them; wherefore I ſhall paſs on to enquire into the Nature of *Taſtes*.

62. That the Qualities of Roughneſs and Smoothneſs have no Difficulty in them.

CHAP. XXIV.

Of TASTES.

THE Word *Taſte* is uſed in Two Senſes. For Firſt, it ſignifies that Senſation which we commonly have when we drink or eat. Secondly, we underſtand by this Word ſomething, I know not what, in the Meat and Drink in which the Power of raiſing this Senſation of Taſte in us, conſiſts.

1. The Meaning of the Word Taſte.

2. Though *Taſte* in the former Senſe of the Word, cannot be exactly deſcribed, nor particularly known but by Experience, yet we may make this Obſervation, that all Men have not the ſame *Taſte* when they eat the ſame Meat: as appears from hence, that ſome Men can eat with Pleaſure thoſe Things which others have an Averſion to: Whence we may conclude, that it is the ſame with *Taſting* as with *Feeling*: For if we touch in the ſame Part, two Perſons, the one in perfect Health, the other juſt recovered of a Diſtemper, they will be very differently affected, *viz.* the one with an agreeable Tickling, and the other with an intolerable Pain; in like manner the ſame Meat may cauſe different Senſations in different Perſons.

2. That all Men do not perceive the ſame Taſte in the ſame Meat.

3. As to *Taſte* in the other Senſe of the Word, which we are principally to inſiſt upon, *Ariſtotle*'s Opinion is, *That it is a Quality or Property of a moiſt Body ariſing from an earthy Dryneſs, and a Heat on being freſh boiled.* This Definition contains Three Things, every one of which have ſome Reſemblance of Truth. And firſt, I think *Ariſtotle* had Reaſon to ſay, that *Taſte* is a Property of a moiſt or liquid Body, becauſe thoſe that are perfectly dry or hard, have no Taſte 'till they are mixed with our Spittle. Further, if we conſider that Water has ſcarce a-

3. Ariſtotle's Opinion concerning Taſtes.

ny Taste, and Air none at all, though they be both moist Bodies, we must confess, that he had Reason to add something more gross, and of an earthy Nature. Lastly, he ought to bring in Heat, because we find by Experience, that in many Fruits it causes certain Tastes which we did not perceive in them before they were prepared.

4. That Aristotle has not explained what Taste is. 4. The Followers of *Aristotle* will readily agree to that Explication which I have given of his Definition of *Taste*; but it must be owned, that though he has said nothing but what is true, yet has he given us no Information at all; because he has not explained what that Affection or Property of Body is which causes Taste, nor wherein it consists.

5. A Mistake in the Commentators upon Aristotle. 5. Some have attempted to supply this Defect, by saying, that it is a Quality very like that Sensation which it raises in us; but they are not at all aware what Inconvenience this brings us into: For besides that this gives to inanimate Bodies a Mode of Existence, which does by no Means belong to them; it would follow from this Opinion, that two Men could never have different Tastes of the same Meat or of the same Drink, contrary to what we have before proved.

6. That Taste consists in the Grosness, Figure and Motion of the Parts of the Body which we taste. 6. On the contrary, since we are already assured, that when the same Meat causes different Sensations in two different Persons, one of them must necessarily have a Sensation different from that in the Thing which raises the Sensation, we have Reason to think the same of the other likewise. It is probable therefore, that *the Faculty of Tasting in us*, is very like *the Faculty of feeling Pain*; that is to say, in order to bring this Power into Act, nothing more is required on the Part of those Bodies which cause Taste, but that they move [1] the small Fibres of the Nerves of the Tongue in such a manner as they ought to be moved, and as Nature has appointed, in order to the Perception of Taste; the same as in order to feel Pain, nothing more is requisite but to move in a certain manner the Nerves which are the Instruments of *Feeling*: And because nothing can move another, unless it be in Motion it self, and nothing can be applied to the Nerves of the Tongue, so as to have any Effect upon them, unless it be of a certain Bigness, and of a certain Figure:

1. *The small Fibres*) Concerning the Organ of Taste, and its Description. Se *Regis's Phys. Book* VIII. *Part* II. *Chap.* iv. *and the famous* Lewenhook's *Epist.*

I there-

I therefore think, that the Form of a Body which causes Taste, consists in *the* 1 *Bigness, Figure and Motion of its Particles*, and that from the Difference which there may be in these Three Things, there may arise different Tastes.

7. Why some Bodies have no Taste.

7. And this is confirmed by a Truth, which follows from what I have supposed, namely, that if the Particles of a Body be so subtil, that they will scarcely or not at all move the Organ of Taste, that Body will have no Taste. And thus we find by Experience, that Water has scarce any Taste, and Air none at all.

8. A particular Reason why Air has no Taste.

8. We may also give a particular Reason why Air has no Taste, *viz.* because it swims upon our Spittle without mixing with it, so as to make any Impression upon the Nerves of the Tongue; by which we may also understand why fat Liquors have not so sharp a Taste as thin Liquors have.

9. Why hard Bodies for the most part have no Taste.

9. Further, if a Body be of such a Nature, as that none of those Parts are separated from it, which are capable of penetrating the Pores of the Tongue, in order to move the Fibres of the Nerves, that Body ought to have no Taste. And so we find, in most Metals, and also in Glass and Flint Stones.

10. How Metals may acquire a very strong Taste.

10. Nor are we to think that there is any Thing in these Bodies, that causes them to have no Taste, but only, the not being divided; for the Salts which belong to the Composition of Glass, tasted very strongly before they were concreted; and Metals which are reduced to a very fine Powder by the Chymists, are of so strong a Taste as not to be born.

11. Why warm Meats have a stronger Taste than those that are cold.

11. Since Heat always increases the Motion of a Body; and since it is also very certain, that the more a Body is in Motion, the more capable it is of moving others to which it is applied; it follows, that when Meat is hot, it must necessarily have a stronger Taste, than when it is cold; as every Day's Experience shows us.

12. Why Meat, when it is made ready, has a different Taste from what it had when raw.

12. It is also very easy to see, that the Heat, in making Meat ready, causes the Particles to strike one against another, so that the Corners of many of them must be

1. *The Bigness, Figure and Motion)* Others contend, that not all the Particles, but the Salts mixed with the Particles of all Bodies, are the Causes of all Tastes; which is handled at large by Mr. *Le Clerc in his Phys. Book* V. *Chap.* xii. And indeed this is a very probable Opinion; by whether the Particles of the Salt only, or any other Particles, be the Cause of Tastes, it comes to the same Thing; for we must necessarily at last have recourse to the Bigness, Motion and Figure of those Particles. *See the Notes on Art.* 38.

broken

broken off, and they by this Means divided into smaller Particles than they were before, and also of a different Figure; and this is the Reason, why Meat, when it is made ready, has a different Taste from what it had when raw.

13. That there ought to be a great many very different Tastes.

13. As to the Difference that there is in Tastes; since we have made them to consist chiefly in the Difference of the Figures of the Bodies so tasting; of which Figures there may be infinite Variety; this agrees with Experience, which discovers to us new Tastes every Day.

14. A Mistake of those who think that all Tastes arise from a Mixture of two Extremes.

14. This being so, I cannot approve of their Opinion, who contend for two extreme Tastes, from a Composition of which they imagine all others to arise. Besides, that it would follow from thence, that all Tastes would differ only in degree; which is contrary to Experience, which shows us, that there is a greater Difference than so.

15. That Sweet ought not to be opposed to Bitter.

15. I do not say that there can be no Instances given of such extreme Tastes, which raise in us the most different Sensations; but if any such are to be allowed, I should rather opppose a *sharp* or *acid* Taste to a *bitter* Taste, and not a *Sweet* to a *Bitter*, as is commonly done; because we do not find that a *sharp* Taste arises from the Mixture of *Sweet* and *Bitter*; but on the contrary, *Sweet* seems rather to arise from the Mixture of the other Two, as we experience in Fruits, the *Sweetness* of which seems to be a Medium, betwixt an *Acid* and a *Bitter*.

16. What Acidness consists in.

16. To attempt to treat of every particular Taste, would be to undertake a Thing impossible, and there are many Things wanting in order to speak with Certainty of the principal and most common ones. However amongst these, some seem more easy to be understood than others, such as *Acid* or *Soure* like *Citron-Juice*. For as this Taste pricks the Tongue, we may from thence conclude, that Bodies which affect us in that manner, consist of a great Number of *long and stiff Particles, which in some measure resemble small Needles.*

17. Why all Fruits before they are ripe are soure.

17. This will seem the more probable, if we consider, that this *soure* Taste is common to all Fruits before they are ripe; for this is a Sign that *Soureness* consists in something which is common to them all; but we cannot conceive any Thing else common to them all, but this Disposition of their Parts, for they are all composed of the Juice of the Earth, which stops in the long streight Pores of the Stock and Branches which bear the Fruits.

18. That

18. That we may underſtand ſomething of other Taſtes, we may conſider the Progreſs of Fruits 'till they come to Maturity; for if we can but once know what Figure the Particles are of, when we experience a certain Taſte, it will be eaſy to conclude, that this Taſte conſiſts in this Sort of Figure. Firſt then, ſince all Fruits are ripened by the Heat of the Earth and Air: (whether this Heat be cauſed by the Rays of the Sun, as commonly happens in Fruits that grow in Gardens, or whether it be produced by Fires kindled under or upon the Earth, as when Fruits are made to grow in Houſes, in the midſt of Winter;) we cannot help thinking, that a great many Particles of theſe Fruits are put into ſo great Motion, as to ſtrike againſt each other in different Manners, ſo that ſome of the longeſt of them are broken into ſhort ones, others have their Points only beaten off, and others are made entirely round. And then it is, that the Fruits have a *ſweet acid* Taſte. Whence it is reaſonable to conclude, that *the ſweet acid Taſte of Fruits conſiſts in this, that ſome of their Particles are long and ſtiff, and prick the Tongue, at the ſame time that a great many other of them are leſs penetrating, and ſo ſlip over the Fibres of the Nerves, without producing any thing more than a kind of Tickling.* *18. What the ſweet acid Taſte of Fruits conſiſts in.*

19. We may obſerve further, that the riper Fruits grow, the more their Particles are broken, blunted and made ſmall; wherefore ſince the Fruits are then *ſweeter*, we ought to conclude, that the great *Sweetneſs* of Fruits ariſes from hence, that they have a far greater Number of thoſe Particles which can only tickle, than of thoſe which prick. *19. How they become entirely ſweet.*

20. But if Fruit continues ripening too long; there is no doubt, but that all its Particles will be ſo bruiſed, that none of them will be able to prick the Tongue agreeably, but they will only tickle it in a diſagreeable manner: Now Fruits when they are too ripe, become *bitter*; whence it is reaſonable to preſume, that *Bitterneſs conſiſts in this, that all the Particles are ſo broken, blunted, and made ſmall to that Degree, that there remains no long and ſtiff ones amongſt them.* *20. What Bitterneſs conſiſts in.*

21. And this is confirmed from hence, that in thoſe Things which are made ready by Art, the Parts of them which are burnt, and whoſe Particles are beaten one againſt another, and have their Corners broken off, are always *bitter*, as we experience in *Cruſts of Bread*, and in *Roaſt-meat when laid too near the Fire.* *21. Why Meats when they are over-made ready, become bitter.*

22. The

22. Why sweet Things may be resolved into two other, the one acid, and the other bitter.

22. The Nature of *Soure, Sweet and Bitter* being thus explained, we shall no longer be surprized, that sweet Things, such as Wine, suppose, may be resolved into two other, the one of which is *soure*, or *acid*, the other *bitter*; for that which makes any Thing sweet, (with such a Sweetness as is agreeable to the Taste) is composed of two Sorts of Particles, in the *one* of which *Acidness* consists, and in the other, *Bitterness*.

23. Why bitter Things are heating, and acid Things cooling.

23. Neither shall we any longer be surprized, that *Orange-Peal, Treacle*, and many purging Medicines have a heating Quality, and that *acid* Things, such as the *Juice of Orange* and *Verjuice*, are commonly cooling; since we are assured, that Heat consists in such a Sort of Motion, as the subtil, round and blunt Particles of *bitter* Things are capable of exciting and continuing; and that on the contrary, the long Particles, of which *acid* Things are composed, being something of the Nature of Water, are more proper to hinder Motion, that is, to quench Fire, than to kindle it; wherefore they ought to be reckoned amongst cold Things.

24. How a bitter Thing may be cooling.

24. Neither is it inconsistent with what has been said, that we sometimes find our selves cooler than we were before, upon *eating* bitter Things; for there are some of them so easy to be corrupted, that they can produce but a very small Heat, such as is scarce to be perceived; but yet this Heat may be enough to cause such an Agitation in the Particles of our Blood, as to carry off some noxious Matter which made it move too quick before, and by this Means it will be put into a more quiet State; and thus we may feel the Heat abated, and our selves cooler than we were before.

25. That the Alteration of Tastes arises from the Alteration of the Figure of the Particles of the Body which we taste.

25. I shall not insist any longer upon the Explication of particular Tastes. It would be very tedious to go through them all, and require a great Number of very exact Experiments, which I have not made, nor perhaps ever shall. But to confirm my own Opinion as much as I can, *that their Difference consists in the different Figures of the Particles of the Body which we taste*; I will examine *one* particularly, and make it appear, that as often as our Reason shews us, that there is any Alteration in the Figure of the Particles, Experience shews us also that there is some Alteration in the Taste.

26. An Instance in Wine, and that the Wood of the Vine ought not to have any Taste.

26. Let us take *Wine* for an Example, and consider it from the very Beginning, 'till it degenerates into something that is not at all like Wine. I observe in the first place, that the *Moisture* of the Earth, because it is composed

posed of the most minute Particles of it, has scarce any Taste, and though in the Pores of the Wood of the Vine it grows in grosser Particles, and such as are able to move the Nerves of the Tongue; yet because it sticks among the Parts of the Wood, and is not easily disingaged from it; therefore it excites but a very small Sensation in those who chew the Wood.

27. Further, since the Particles of the Juice which get into the Air and distill through the Stalk of the Bunch, in order to form the Grapes, stick together, and cannot easily be separated; it follows, that they can apply themselves to the Superficies of the Tongue only, and consequently that they can raise but a small Sensation scarce to be perceived. And so we find by Experience.

27. That a Bunch of Grapes, when it is first formed, ought to have very little Taste.

28. But some time after, when the Particles, of which the small Grapes are composed, are separated from each other, either by the Heat of the Air which agitates them gently, or by the Accession of more similar Particles which thrust themselves in to increase the Bulk of them; it is manifest, that they ought then to act separately, and to raise the Sensation of a very sharp Taste, such as we experience in Verjuice.

28. Whence arises the very sharp Taste of Verjuice.

29. And the Heat of the Air, which increases as the Fruit ripens, continuing to move the Particles of the *Grapes*, it is evident, that they must be more and more blunted thereby, and some of them made so very small, as only to tickle the Tongue agreeably, and to excite that Sensation of *Sweetness* which we feel in chewing the *ripe Grapes*.

29. How Grapes grow sweet.

30. We see also, and it is an Observation worth taking Notice of, that if it be wet Weather about the Time of gathering the Grapes, the Water which sinks into the Earth, will afford too much Nourishment to the Grapes: Wherefore as there are too great a Number of long Particles, which there is not time for breaking or blunting, it follows, that the Grapes will not be so sweet as they would otherwise have been. And this is often found by Experience: For if it rains a little before the Vintage, the Wine is sharper, or, as they call it, harsher. This the People of *Languedoc* seem to be aware of, who are at the Trouble, a little before the Season of gathering the *muscadine Grapes*, to twist the Stalks of all the Bunches, that so they may ripen, and not receive any more new Nourishment.

30. Whence it is that the Wine is sharp if it rains during the Vintage.

31. For

31. *The Reason why new Wine is sweet.* 31. For a further Confirmation of what I have said, it is worth obſerving, that if we taſte of the Juice of the Grapes *juſt after they are preſſed*, there ought to be very little Difference from the Taſte of the Grapes themſelves; and it ought alſo to continue its Sweetneſs for ſome time after it is put into the Veſſel, provided the Veſſel be well ſtopped. For though, while it is working, many of the long Particles which are intangled in one another, have an Opportunity of getting clear, and ſo are capable of pricking; yet however they cannot cauſe any ſharp Senſation, becauſe they act in Company with a great many others which have had ſufficient time to be broken and made ſmall, having been preſerved in the Veſſel carefully ſtopped up: And this agrees very well with the ſweet Taſte which we find in *New Wine before it is fined.*

32. *Why Wine grows ſharper by working.* 32. If while the Wine is working in the Preſs or Vat, and while it continued to work in the Veſſel, the moſt ſubtil Particles, which have moſt Motion, and which by reaſon of their Smallneſs were leſs ingaged with the other, be permitted to fly away, and evaporate into the Air through the Bung-hole, which is left open for that Purpoſe, there muſt neceſſarily remain fewer of thoſe Particles which tickle the Tongue, and more of thoſe which prick it. And this is the Reaſon why we ought then to find the Taſte ſharper, that is, ſuch as we experience in *Wine not quite fit to drink.*

33. *How it loſes this Sharpneſs.* 33. After this, we may conſider the Wine in two Conditions: Firſt, let us ſuppoſe it ſtopped up in the Veſſel ſo cloſe, that it has not the leaſt Communication with the external Air; in which Caſe ſome of its Particles will be broken and blunted, and a great many of thoſe which remain whole, will loſe their Stiffneſs, and become plyable, by rubbing againſt one another, and bending in that ſtrait Place in which they are incloſed; and by this Means they will be leſs capable of ſhaking the Nerves of the Tongue: Wherefore the Wine will no longer taſte *Sharp*, but attain that Sweetneſs which we experience in it when it is *fit to drink.*

34. *How it may become very ſweet.* 34. And without doubt the Sweetneſs would increaſe continually, if the Wood of the Veſſel did not change the Liquor a little, and permit the more ſubtil Parts of it to evaporate through its Pores. For a Proof of which, we may remember, that Wine kept many Years in earthen Bottles, well ſtopped, and put into Sand in the Bottom of

the Cellar, will in length of Time become as ſweet as Honey.

35. Suppoſe now, that the Veſſel be not ſtopped; the long Particles which ſlip by one another, may be ſo worn as to be a little diminiſhed, but there is no Neceſſity that they ſhould become limber and pliable: For thoſe of them that are moſt limber, are at liberty to evaporate through the Hole of the Veſſel, and thoſe which remain have the more room to move in without being forced to bend themſelves. So that all the Alteration that will happen to the long Particles which remain, is, that they will become more ſharp, and the Wine will be converted into a Liquor which will prick the Tongue more ſharply, that is, it will be turned into *Vinegar*. *35. How it may grow ſharp.*

36. If the Particles ſtill continue to be thus moved for a conſiderable time, they will at laſt be ſo worn, and become ſo very ſlender, as to be extremely pliable, inſomuch, that they will have no Power at all to move the Nerves of the Tongue; and then the Liquor compoſed of them can have no Taſte, and be very little different from Water; as we find by Experience. *36. How Vinegar may be turned into a Liquor that may have no Taſte.*

37. For a final Confirmation of what I have ſaid concerning Taſtes, I will relate an Experiment which I made my ſelf: I took a Pewter Pot, and having made a Hole in the Bottom of it, I ſtopped it with a Piece of Cloth, and then filled it about half full of very fine Sand, ſo well waſhed, as not in the leaſt to tincture the Water which drain'd through, and afterwards well dried: After this, I put in a Quart of full-bodied Red-Wine, which diſtilling through the Hole below, there came out about a Pint of clear Liquor like Water, which had no Taſte: Then perceiving that the Drops began to be tinged with Red, I took away the Veſſel which I had ſet under, and put another in its Room, into which there ran pretty near the other Pint; and this laſt was much leſs red, and had a much fainter Taſte than the Wine it ſelf before it paſſed through the Sand. Laſtly, mixing this Liquor with the other, which was very clear, the Reſult was a Liquor of a very faint Colour, and ſcarce any Taſte. *37. A remarkable Experiment.*

38. I think no Body that knows what Sand is, can find out any other Reaſon for the Alteration of the Taſte of the Wine by paſſing through it but this, that the Particles of the Wine being forced to go through very narrow winding Paſſages, are bent a great many times all *38. The Concluſion of this Chapter.*

N Ways,

Ways, and [1] have the Figure and Condition of them changed: From whence we may conclude, that [2] *the Form of all Bodies that have any Taste consists in the Disposition and Figure of their Particles.*

1. *Have the Figure*, &c. The Figure of them is not altered, but only the Parts which have no Colour or Taste, are separated from the red Parts which have a Taste.

2. *The Form of all Bodies*, &c.) That Taste consists wholly in the Figure and Composition of the Parts is clearly demonstrated by the famous Mr. *Boyle*, from the surprizing Alteration of Tastes, by variously compounding of Bodies. I think it worth while briefly to propose the Experiments made by that excellent Person, because they ought to be kept in Memory.

First, *From two Bodies, one of which is very acid and corrosive, the other alkalious and fiery, may arise a Body without almost any Taste.* This is done by a certain Composition of *Spirit of Nitre* and *Nitre fixed* per deliquium.

Secondly, *A Body that has scarce any Taste may be separated into two Bodies of a very sharp Taste, yet very different from each other.* This is done by distilling the most refined *Salt of Nitre by Inflammation*, or with a Mixture of Clay which has it self no Taste.

Thirdly, *From two Bodies, one of which is very bitter, and the other very salt, may arise a Body which has no Taste.* This is done by sprinkling *Crystals of Silver* dissolved in *Aqua-fortis* with *Brine* or *Salt Water*, and then melting and preparing them on the Fire till they come to a *Lunea Cornea* as the Chymists call it.

Fourthly, *From two Bodies mixed together, one of which is very sweet, and the other very salt, may arise also a Body which has no Taste.* This is done by pouring a certain Quantity of Spirit of *Sal Ammoniac* or *Salt of Urine* upon *red Lead* dissolved in Vinegar, or *Sugar of Lead* dissolved in a proper *Menstruum*.

Fifthly, *From two Bodies, one of which is acid, and the other has no Taste, may arise a Body very bitter.* This is done by straining *Aqua-fortis* saturated with dissolved *Silver*; For it will afford very bitter *Crystals*.

Sixthly, *From two Bodies mixed together, one of which is insipid, and the other very corrosive, may arise a Body sweeter than Sugar.* This is done by pouring the best *Aqua-fortis* upon *red Lead*, and then putting it over a moderate Fire till it is saturated.

Seventhly, *From the sweetest Bodies of all, without mixing any other Bodies with them, may be extracted very corrosive Liquors, such as will dissolve certain Bodies.* Thus a Spirit that will dissolve *Copper* may be extracted from *Sugar* or *Honey*.

Eighthly, *A Body as bitter as can be, may be separated into two Bodies, one of which is very acid, and the other without any Taste.* Thus a very acid *Spirit* may be extracted from *Crystals of Silver* distilled over a very hot Fire, and a *Body without any Taste* will remain at the Bottom.

Lastly, *The same Body dissolved in different Liquors, as* Aqua-fortis, Aqua-regia, *Spirit of Salt, distilled Vinegar, Spirit of Urine, &c. will have a different Taste in each of them.* So also, *the same Liquor, as* Aqua-fortis, *mixed with different Bodies, will have different Tastes*, thus with Silver it will be *bitter*, with Lead it will be *sweet*, with Copper it will be *intolerable*. See *Boyle of the Production of Tastes.*

CHAP. XXV.

Of SMELLS.

BY the Word *Smell*, we may firft underftand that particular Sort of Senfation which is raifed in us by the Impreffion of certain Bodies upon 1 the Nerves of the internal Parts of the Nofe: And we may alfo underftand by it, *that* in the Body which fmells, in which the Power of exciting the Senfation of *Smell* in us, confifts. *1. What is meant by the Word Smell.*

2. Every Body knows by their own Experience what *Smell* is in the former Senfe of the Word, but it is impoffible to defcribe and make fuch Preception known to others. All that we can fay, is, that the fame Object does not raife the fame Senfation in all Perfons, a great many finding certain Perfumes agreeable to them, which others cannot bear. *2. That the Senfation of Smell is not alike in all Perfons.*

3. This being fo, we fhall only endeavour to find out what *Smell* is with refpect to the Body fmelling. *Ariftotle* has not defined it at all in that Chapter where he treats expreflly of Smells, and 2 where he makes this Excufe, that Men have not their Smell fo perfect as other Creatures. *3. That Ariftotle has not defined what Smell is.*

4. Some of his Followers think they underftand what he means 3 from that Place where he fays, *That the Inftant we perceive any Thing, we become like the Object which acts upon us to caufe that Senfation:* And upon this Foundation it is, that they contend that Smell in the Object is fomething very like that Senfation which it raifes in us. To which they add, that *Smell* arifes from the Mixture of hot and cold, dry and moift, but fo that the hot and the dry prevail moft. *4. The Opinion of the Ariftotelians.*

5. But befides, that this Opinion afcribes to inanimate Bodies, a manner of Exiftence which agrees to thofe only that are animated, which cannot be; it would follow, that the fame Smells muft be equally agreeable to all Perfons, contrary to what was obferved before. To which we may add, that it is wholly inconceivable, (fup- *5. A Confutation of this Opinion.*

1. *The Nerves of the internal Parts*) For the Organ of Smelling, and the Defcription of it. See *Regis Phyf.* B. 8. *Part* II. *Chap.* v.

2. *Where he makes this Excufe*) *It is not fo evident what Smell is, as what Darknefs or Light* [illegible] *Colour are. The Reafon is, becaufe we have not this Senfation very perfect, but worfe than many other Animals; For Man's Smell is very bad,* Arift. de Anima. lib. 2. cap. 9.

3. *From that Place*) See the Notes on Chap. xxiii. Art. 7.

pofing

posing the Idea's which the *Aristotelians* give us of the four principal Qualities that come under the Sense of Touching to be true) that the Mixture of them should produce any Thing else but Warmness, which will be more or less dry or moist, according as it has more or less of those Qualities mixed with it, which has no Similitude at all to that Idea which they give us of Smell. Lastly, If this Mixture were Smell, as we perceive it by Touch, it ought to raise a Sensation like to it self in all Places where the *Organ* of Touch is; and then we ought to smell with our Hands as well as with our Noses; which is contrary to Experience.

6. What the Nature of Smells consists in.

6. If to this it be answered; that That which causes the Sensation of Warmness, when it acts upon the Hand, may also excite the Sensation of Smell, when it acts upon the Nose, Nature having so ordered it: I agree with them. But because I know nothing else in Bodies but *Magnitude*, *Figure* and *Motion*, I cannot think there is need of supposing any Thing else to make them capable of impressing Smell upon the *Organ of Smelling*: Wherefore I am of Opinion, that the same Particles which raise the Sensation of Taste, when applied to the Tongue, may also raise the Sensation of Smell, when being so very small as to fly about like Vapours or Exhalations, they come to tickle those two extended Parts of the Brain which answer to the most inward Recess of the Nose.

7. Why Smells are more perceived when it is hot, than when it is cold.

7. This may be proved from hence: First, That we experience, that the greater the Heat is, and consequently the more capable of making a greater Number of such Particles as cause Smell, to fly off; the further do Bodies extend their Smell: And on the contrary, as the Cold keeps their Particles at rest, and hinders them from exhaling, so it is the Cause of their Smell's being less perceived.

8. Why certain Bodies cease to smell.

8. Further; we observe, that a great many Bodies smell no longer than whilst they are moist, that is, so long as some of their Particles are in Motion; and that they cease to smell when they are quite dry, or have all their Particles at rest.

9. How Bodies which seem to have no Smell, may send forth some Smell.

9. Lastly, One of the most evident Proofs that we have to show that Smells consist in the Evaporation of certain Particles, is this; that most hard Bodies, which do not of themselves, as we say, raise the Sensation of Smell, when they come to be burned, or only to be rubbed one against another, appear to have a Smell; because by these Means some of their Particles are made to evaporate.

Thus

Thus *Sealing-Wax*, when it is lighted, raiſes a Smell, which was not perceived before. And thus Iron rubbed againſt Iron, and one Flint againſt another, raiſe a Smell alſo which was not perceived before.

10. I do not however pretend to affirm, that all Sorts of Particles which are carried off from all Sorts of Bodies, ought indifferently to raiſe the Senſation of Smell; For in order thereto, there ought to be a certain Motion of the *Organ* of Smelling, and a certain Force to ſhake it; and there may be alſo Particles ſo very ſmall as not to be able to ſhake it the leaſt that is poſſible: Thus, the Air which we breath, and the Vapours which riſe out of Water, have no Smell at all; and, on the contrary, there may be others ſo large as that they may not come to the *Organ* at all, or if they do come to it, are rather capable of quite ſpoiling it, than of ſhaking it in ſuch a manner as may raiſe the Senſation of Smell. *10. Why ſome Bodies have never any Smell.*

11. The Difference of *Smells* depends upon the ſame Cauſe as the Difference of Taſtes does, that is, 1 *upon the Difference there is in the Bigneſs and Figure of the Particles* *11. Wherein the Difference of Smells conſiſts.*

1. *Upon the Difference*) That Smell, in the ſame manner as Taſtes, conſiſts entirely in the Compoſition and Figure of the Parts, is very evident from the following Experiments made by the Famous Mr. *Boyle*.

Firſt, *From two Bodies mixt together, each of which is without any Smell, may be raiſed a very ſtrong urinous Smell.* This will be, if *unſlacked Lime* and *Sal Ammoniac* be beaten together.

Secondly, *By a Mixture of common Water, which has no Smell, a Body which has alſo no Smell, may be made to ſend forth preſently a ſtrong Smell.* Thus, *Camphire* diſſolved in *Oil of Vitriol* has no Smell, but mixed with *Water*, it immediately ſends forth a ſtrong Smell.

Thirdly, *Compound Bodies may ſend forth Smells which are not at all like the Smells of the Bodies ſeparate.* Thus *Oil of Turpentine* mixed with double the Quantity of *Oil of Vitriol*, after it is diſtilled, will not ſmell of Turpentine but of Brimſtone; and that which remains in the Retort, if it be forced with a ſtronger Fire, will reſemble the Smell of diſtilled Oil of Wax.

Fourthly, *A great many Smells may be raiſed only by Motion and Agitation.* Thus a Multitude of Bodies, as *Glaſs*, *Stones*, &c. which, though heated, ſend forth no Smell, yet if agitated and bruiſed with a particular Motion, ſend forth a very ſtrong Smell; and there comes a Smell like that of a Roſe, out of *Beech-wood* while it is turning.

Fifthly, *A Body that has a ſtrong Smell, mixed with another Body that has no Smell, may loſe all its own Smell.* Thus if *Aqua fortis* not too well dephlegmated he poured upon *Salt of Tartar*, till it ceaſes fermenting; that Liquor, after evaporation, will afford Cryſtals without any Smell, like Salt of Nitre; but if they be burnt, they ſmell as bad as can be.

Sixthly, *Out of two Bodies mixed together, one of which has the worſt of Smells, and the other not a very good one, may ariſe a pleaſant aromatick Smell.* This is done by a certain Mixture of *Aqua fortis* or *Spirit of Nitre* with *imflammable Spirit of Wine*.

Seventhly, *Spirit of Wine mixed with a Body that has ſcarce any Smell, may produce a pleaſant aromatick Smell.* Thus an equal Quantity of *inflammable Spirit of Wine* and *Oyl of Dantzick Vitriol*, mixed together,

ticles which are exhaled from the Body that smells. As will be evident to any one who considers that those Things which have the same Taste, have also the same Smell: Thus all sharp Bodies have a sharp Smell, and all bitter Bodies have a Smell that has something of Bitterness in it.

12. How the same Body may send forth different Smells one after another.

12. And this is so true, that when we are once assured that the Particle of certain Bodies have changed their Figures, we always find by Experience, that they have changed their Smell also. Thus, *the Matter gendred in the Abscess of a Land Beaver,* exposed for some Days together in the Sun, in a hot Country (which without doubt dashes the Parts one against another, and alters their Figure) sensibly alters its Smell, and as strong as it was, it becomes first tolerable, and at last is turned into that valuable Perfume, which we call *Musk.*

13. How the Bulk of smelling Bodies diminishes by little and little.

13. From what we have said concerning the Nature of smelling Bodies, we may conclude, that both their Bulk and their Weight diminish by little and little. Thus we find by Experience those Smells to be quickly over, which are raised by burning: But as to those which we perceive without heating the Bodies, such as those of *Musk* and *Civet,* [1] it is a long time before they are sensibly diminished, because the Motion of their Particles is very slow, and but a few of them are exhaled at a time. And as but a few of them are exhaled at once, they could not move the Sense, without meeting and mixing with a great many others, which were sometime before evaporated, and flew about the smelling Body.

together, and digested, and then distilled, will afford a penetrating Spirit of a very pleasant Smell.

Eighthly, *A Body of the most pleasant Smell, without mixing any other Body with it, may degenerate into the worst stink.* Thus *the Spirit mentioned in the foregoing Experiment,* if it be kept stopped up in a Bottle, will in a short time degenerate into the strong Smell of Garlick.

Lastly, *Out of two Bodies, one of which has no Smell, the other a bad Smell, may arise a pleasant Smell like that of Musk.* This is done by putting *Pearls* into *Spirit of Vitriol.* For while they are dissolving, they send forth a pleasant Smell. See *Boyle of the Production of Smells.*

1. *It is along time,* &c.) Whoever considers the infinite Divisibility of Matter, and the inconceivable Smallness of the Parts of Light which always find an easy and open Passage through Glass and Diamonds on all Sides, and every Way, will, I believe, have no doubt, but that it is wholly owing to the *Smallness* only of the Particles emitted, though they may be very much larger than the Particles of Light, that Bodies which have a Smell, are yet a very long time before they are sensibly diminish'd.

CHAP.

CHAP. XXVI.

Of SOUND.

THE Word *Sound* was intended to signify in the first Place, that particular Sensation which is raised in us, by the Impression made upon the Ears by what we call sounding Bodies. And the same Word is also used to signify *That* in the sounding Bodies, as in a *Bell* or in the *Air* which surrounds it, which causes in us the Sensation of Sound. *1. The Word Sound has two Meanings.*

2. After what has been observed when we spoke of Tastes and Smells, it is needless to say, that *Sound*, taken in the former Sense of the Word, cannot be described, or known any other Way but by Experience. Wherefore we shall treat of it here only as *That* in the *sounding Bodies* or in the *Air*, which we call *Sound*. *2. In what Sense we are here to understand the Word.*

3. *Aristotle* has [1] a Chapter particularly upon this Subject, wherein he asserts, *that Sound is nothing else but the local Motion of certain Bodies, and of the Medium applied to the Ear*; and that we may be sure that this is his Notion, he repeats it above twenty times. *3. Aristotle's Notion of Sound.*

4. I take particular Notice of that extraordinary Care which *Aristotle* took, to make us understand the Notion he had of the Nature of Sound. For though he repeated it so often, that it may seem troublesome to some Readers; yet I find, he has not said it often enough for some others, who professing to follow his Opinions in other Things, do notwithstanding believe that *Sound* is a Quality different from local Motion *4. The Notion of some of his Followers.*

5. There are some, who, to maintain this Opinion, and confute that of *Aristotle*, say, that if *Sound* be nothing else but *local Motion*, it would follow, that in moving our Hand, for Instance, we ought to perceive some Sound; and there are others who assert, that according to this Notion, it must follow, that a Bell which is heard two Leagues every Way, must move the Air so far all round, which they think absurd. *5. What Reason they give for it.*

6. However, these Objections are of no Weight; for as to the first, it proves no more than this; that Sound *6. That they are mistaken in differing from Aristotle.*

1. *A Chapter particularly upon this Subject*) Chap. viii. Book 2. Concerning the *Soul*.

does not consist in all Sorts of Motion, and especially not in such a Motion as is given to the Hand when it is moved; which indeed is very true. And as to those who think it absurd, that a *Bell* should move the Air for two Leagues round, they judge of Nature only by their own Prejudices, which are no Proofs.

7. That the sounding Body does not cause all that Motion which is requisite to produce Sound.

7. I confess indeed, that some Force is required to put a Mass of Matter, which is extended two Leagues round in Motion; But the Effect produced by the *Bell* is not so great as we may imagine: For when it moves the Air in this manner, [1] it only acts upon a Body, which was in Motion before as it is a liquid Body. So that it does not so much act upon it to give it Motion, as to determine that Motion which it had before, in such a Manner as is proper to produce in us the Sensation of Sound.

8. That it is not at all difficult to put some Bodies in Motion, which seem hard to be moved.

8. I say further, that it is not so difficult as is imagined, to cause such Sort of Trembling in a Body which is every way surrounded with a Liquid: Experience shows us this in a large Anvil, (which doubtless is one of those Bodies which are not apt to be put in Motion;) for we see it trembles upon the least Blow given it by the Hammer; and we may observe, that if a few Grains of Millet be put upon it, and it be struck on the Side with a moderate Key, according as the Sound is more or less, the Grains of Millet will jump higher or lower, and change their Place on the Anvil. Now it could not cause this Motion in the Grains, if it was not moved it self.

9. That Sound consists in a certain sort of Motion only.

9. And to show that *Sound consists in a particular Sort of Motion*, we need only consider, that it is always produced when we strike our Fingers over the Strings of a Lute, or when we strike against any hard Body. Now to strike the String of a Lute, or to strike any hard Body, is nothing else but to move the String out of its Place, or to put the Body in Motion. And it is very absurd to think, as the *Aristotelians* do, that the Constitution of them is altered, and that we make them to acquire some Heat or Cold, some Dryness or Moisture which they had not before.

1. *It only acts upon a Body,*) The Motion which is in the Air before it is moved by the Sounding Body, contributes nothing at all towards producing Sound. For as many Particles of Air as there are, tending the same way as they are impelled by the sounding Body, and therefore more easily yielding to it than if they were at rest; just so many ought we always to think are moved the contrary way; and for that Reason resist the Body in Motion more than they would do if they were at rest.

10. And

10. And this is confirmed from hence, that if the Ear be tickled in the infide fo as to make any Impreffion upon what [1] the Phyficians call the *auditory Nerves*, we find a certain Tingling. Whence it is evident, that it is the fame with the Senfation of Sound as with that of Pain; and both the one and the other fhows, that by the Appointment of the Author of Nature we are made fo, that when certain Nerves are moved after a particular Manner, we fhould have a particular Senfation. *10. A Proof of the Truth of this.*

11. I can't omit here an Experiment which is often made ufe of to divert Children, and which wonderfully confirms this Opinion. They put a long Thread through a pair of Tongs, and wind each End of the Thread about their Fore-fingers, and then ftop both Ears with thofe Fingers; then moving their Bodies backward and forward, they tofs the Tongs in the Air, and hit them againft the Andirons, or any other hard Body. Now though thofe that ftand by, hear but a moderate Sound, yet the other hear a Sound as loud as that of a large Church-Bell. It is impoffible to folve this any other way, but by faying, that the Motion of the Tongs fhakes the String, which gives its Impreffion to the Fingers, and thefe move the Parts of the Ear, to which they are applied, and by this Means the Nerves of the Organ of the Ear are alfo moved. *11. Another Proof.*

12. Being affured that Sound confifts only in *fome Sort of Motion*, all that remains, is to determine *what Sort of Motion that is*: And here I cannot agree with *Ariftotle* who would have Sound to be *the Motion of a Body that is hard, polifh'd and concave*; for it is certain, that there are a great many founding Bodies which thefe Qualities do not belong to; and alfo, that there are none of them in Gunpowder when it takes Fire in a Cannon, which yet makes fuch a prodigious Noife. *12. A Miftake of* Ariftotle's *upon this Subject of Sound.*

13. Some perhaps, out of Zeal to this Philofopher, may attempt to defend his Opinion, by faying, that if thofe Qualities required by him in a founding Body, are not to be found in the kindled Powder, nor in the Air which is fhaken; yet they are in the Cannon, upon which he would make the Whole of the Sound to depend. But without amufing one's felf to find out Reafons to confute this Opinion; it fhall fuffice to alledge the Experiment of what the Chymifts call *Aurum Fulminans*. What they call fo, is only a Compofition of three Parts *13. The weak Defence of fome of his Followers. And of* Aurum Fulminans.

1. *The Phyficians call the auditory Nerves*) Concerning the Organ of Hearing and its Defcription, See *Regis Phyf. Book* VIII. *Part* II. *Chap.* vi.

of

of Salt-Petre, two of Flowers of Sulphur, and one of Salt of Tartar, beaten feparately in a Mortar, and then mixed together. We muft take about as much of this Mixture as we do of Gun-powder to prime a Musket, and lay it upon an Iron-Plate, or a flat Tile, and put it upon a Chafingdifh of Fire; then the Powder will grow hot gradually, and be at once [1] turned into a Flame, which dilating it felf every way, caufes a Sound almoft as loud as the Report of a Musket well charged. In this Experiment, the Iron Plate or the Tile, ferves only to hinder the Powder from taking Fire, 'till it is equally heated all over; and fince the Sound depends upon the Flame and the Air, which are neither hard, nor polifhed, nor concave, without doubt this Opinion of *Ariftotle's* cannot be fupported.

14. That Sound confifts in a particular fort of Motion.

14. We choofe rather to fay, that Sound confifts in *a particular Sort of Motion of Bodies,* than to fay with *Ariftotle,* that it confifts in the *Motion of a particular Sort of Bodies.* For a more diftinct Explication whereof, we may obferve, that the Bodies which we call founding Bodies, are not applied immediately to our Ears, in order to excite the Senfation of Sound, but for the moft part act by the Interpofition of the Air which they put in Motion; wherefore we ought to find out what the Motions of each of thefe are, when they produce this Senfation in us.

15. That this Motion may be confidered in the founding Body, and in the Medium.

15. There are fome Inftances in which it is eafier to find out the Manner in which *the founding Body* is moved; and there are others in which it is eafier to find out the Motion of the *Air.* The former of thefe we will firft explain as far as we are able, *viz.* the Manner in which *founding Bodies* are moved.

16. What the Sound of the String of a Lute confifts in.

16. And to begin with *the Lute,* or any fuch kind of Inftrument that is plaid upon with the Fingers; it is to be obferved, that the Strings being ftretched, are as ftreight as is poffible, and that in playing upon them they are put out of their Pofition, and bent a little by the Fingers; but as foon as they are let go, they return again to the Place out of which they are moved, and the Velocity which they acquire in returning, makes them go a little beyond it; then they come back, and go a little beyond the Place of Reft again; and thus they go and come feveral times, or have feveral Vibrations, and in this *trembling Motion* confifts their Sound.

1. *Turned into a Flame*) See this Phænomenon explained in the *Notes* on *Part* III. *Chap.* ix. *Art.* 13.

17. The

17. The Sound of the Strings of a Violin conſiſts in the Agitation they are put into by the moving of the Hair of the Bow over them which is made rough and jagged, almoſt like a Saw, by being rubbed with Roſin. Which is ſo true, that if the Hair of the Bow be rubbed with Tallow or Oil, the Strings will have no Sound, becauſe they ſlip under it, and are not ſhaked by it.

17. What the Sound of the String of a Violin conſiſts in.

18. The Sound which a Drinking-Glaſs makes when the Finger preſſing hard upon it moves round the upper Edge of it, conſiſts in the Vibrations like thoſe of the Strings of a Violin; it being evident, that the Finger here ſupplies the Place of a Bow.

18. What the Sound of a drinking-Glaſs conſiſts in.

19. The Sound of a Bell conſiſts in a Trembling, pretty much like that of the String of a Lute: For it is certain, that the Blow given it by the Clapper alters its Figure a little, ſo that from being round, it becomes oval: And becauſe it is made of Metal very ſtiff and ſpringy; that Part which is moſt diſtant from the Center, returns towards it, and ſomewhat nearer than it was at firſt, ſo that the Places which were at the Extremities of the longer Diameter, are the Extremities of the ſhorter one; and thus the Circumference of the Bell changes its Figure by Turns, all the time it is ſounding.

19. What the Sound of a Bell conſiſts in.

20. It will be very eaſy for any one to believe what is now ſaid, if he obſerves, that in laying his Hand upon a large *Bell* juſt when the Clapper ſtrikes againſt it, he will feel a manifeſt Numneſs.

20. A Proof of ſuch Trembling.

21. If the Bell be very ſmall, as the Trembling is eaſily ſtopt by putting our Hand to it, ſo ought the Sound to ceaſe alſo. And indeed there are very ſmall Bells, which if they be but very lightly ſtruck, will ſound for a long time; but if we lay our Hand upon them as ſoon as they are ſtruck, their Sound will immediately ceaſe.

21. Why a ſmall Bell, when touched, ceaſes to ſound.

22. But the Sound of a great Bell is not ſo eaſily ſtopped by laying our Hand upon it, becauſe it has more Motion, and becauſe it can transfer ſuch a ſmall Part of its Motion to the Hand, and reſerve enough to make it be heard.

22. Why the Sound of a great Bell is not ſo eaſily ſtopped.

23. The Sound raiſed by ſtriking a Piece of Wood, or in general, any hard ſounding Body, conſiſts in a Trembling, like that of a *Bell*, which is owing to its Springineſs.

23. Why a Body ſounds when it is ſtruck.

24. Wherefore Bodies, which have not this Property of Springineſs, have only a very low and imperfect Sound: And

24. Why ſome Bodies have but little Sound.

And this is the Reason why *Lead and Clay*, when they are struck against, have scarce any Sound.

25. What sort of Motion of the Air it is in which Sound consists. 25. After what has been said, it will not be very difficult to determine what sort of Motion it is in the Air which produces in us the Sensation of Sound; for it is evident, that 1 this Motion of the *Air* must necessarily be such, as the Trembling of the Sounding Bodies is capable of producing in it: that is, the Air ought to tremble, and bubble, and also by rising and falling, to divide it self into an infinite number of very small Particles, which by trembling and striking against one another, must have a very quick Motion; so that the Air must be something like a Liquor that simpers and does not quite boil. This is confirmed by what we see of a Motion very like this in a large Tub of Water, by moving a Stick backwards and forwards in it very quick; for this Motion of the Stick is very like that of the Strings of a Lute, only these are much larger and the other slower.

26. A visible Demonstration of this Motion. 26. We may be certain of this Motion or Trembling of the Air, if we consider that the sounding Body ought to impress the same sort of Motion upon it, that it does upon other Liquors. Thus, if a Glass be half full of Water, and we make it sound in the Manner beforementioned, by moving our Finger along the upper Edge of it; it must without doubt shake the Air as it does the Water; 2 now we see the Water tremble and boil, and also by jumping out, batter and break it self in such a manner, that a great many small Drops fly a good way out of the Glass. Whence we must conclude, that the Air has the same Sort of Trembling or Boiling.

1. *This Motion of the Air*) For the Parts of the sounding Body going and coming by Turns, thrust and drive forward as they go those Parts of the Air which are next them, and by pressing upon them, condense them; then by returning, they permit the Parts thus compressed, to spread and dilate themselves again. Those Parts of the Air therefore which are next to the sounding Body, go and come by turns agreeably to the tremulous Agitation of the Parts of the sounding Body; and in the same manner as the Parts of that Body agitate these Parts of the Air, do these, being agitated with the same Sort of Tremblings, agitate those Parts that are next them; and these in like manner agitate those beyond them, &c. This being allowed, the manner how the Pulses are propagated along, and all the other Phænomena of Sounds, are very advantageously explained. See *Newt. Philosoph. Princip. Mathemat. Book* II. *Prop.* 43, &c.

2. *Now we see the Water tremble*) You may see a Case of this Experiment very well worth observing in *the Notes on the 45th Art. of this Chapter.*

27. After

27. After having sufficiently shown the Motion of the Air, which is necessary to make us hear any Sound: It is easy to conceive that the Air in passing by some hard and immoveable Bodies, may move it self sometimes in such a manner. Thus, when we whistle, by blowing into the *Hollow of a Key*, it happens, that the Air which enters in, fills one half of the Hole, and the Air which comes out fills the other half; and these two Parcels of Air sliding by one another with contrary Motions; a great many of their Parts must necessarily be made to turn round and to tremble, and the whole Air which is betwixt him that whistles and him that hears must also be made to turn round and to tremble. *27. Whence that Whistling arises, which is made by blowing into the Hole of a Key.*

28. We may observe here, that there are Bodies, which are opened by Fits to let the Air through, and which by this means cause us to hear a particular Sound, which is also a very considerable one. Of this Sort are the Rows of Pipes which compose an Organ, or the single Pipe of a Bag-pipe. These Bodies themselves are not moved in order to produce Sound; but the Air being first put into Motion, endeavours to pass through them, but is forced to go out trembling, and so impresses on the rest of the Air the same Sort of Tremblings as the Strings of a Violin do, and so causes us to hear a Harmony, the Motions of which are Trembling. *28. How the Sound of an Organ-Pipe or Bag-pipe is made.*

29. And in the same manner is the *Voice of Animals* formed: For there is a small Valve at the End of the Trachea, which performs the Office of the Valves of the Tubes which compose an Organ; which Valve we can contract as we please, and let the Air out of the Lungs by Fits. And because this Valve for the most part continues open, therefore the Air in Respiration comes out commonly without any trembling, and consequently without making any Noise. *29. How the Voice of Animals is formed.*

30. It would be too tedious to explain particularly all the different Manners in which Sound is produced. But because there is something singular in the Sound of a *Cannon* when it is discharged, because the Flame seems to give but one and not a repeated Shake to the Air, therefore it may be worth while to explain how such a prodigious Noise is made. It is to be observed then, that the Gun-powder, when it takes Fire, [1] is so extraordinarily dilated, as to take up above a Thousand times the Space *30. Why a Cannon makes a Noise when it is discharged.*

1. *Is so extraordinarily dilated*) For the true Reason of this Dilatation, See the *Notes on Part.* III. *Chap.* 9. *Art.* 13.

that

that it did before; ſo that it drives before it every Way all the Parts of the groſſer Air which was in this Space, and theſe Parts can find no where to go, but by preſſing upon other Parts, and driving them on likewiſe; and at the ſame time they ſqueeze out the ſubtile Matter which mixing with the Powder, compoſe that ſenſible Maſs which we call Flame. Hence it follows, that there is in the Air two contrary Motions; the one of which gathers together and unites the moſt ſubtile Parts, and the other diſperſes the groſſer ones. And this would be done in a Moment, but that the groſſer Air which is condenſed all round, has a Tendency to return into that Place out of which it was driven, and towards which, after the Violence of the Flame is over, its own Weight forces it, and that with ſuch an Impetus, that it becomes more denſe than it ordinarily is; whence it will be reflected again all round, or condenſed anew; becauſe being rarefyed again, it returns to the Place which it had quitted; and thus it quits and takes again the ſame Place ſeveral times ſucceſſively; and this is the Reaſon of that ſhort Continuance of the Noiſe of a Cannon when it is diſcharged.

31. That the Senſation of the Sound continues longer ſometimes than the Sound it ſelf.

31. However it is to be obſerved, that the Ear may ſometimes be ſo ſtrongly moved, that it may continue to tremble ſome ſhort time after the Air has done trembling; and for this Reaſon, the Senſation of Sound may ſometimes continue after the Agitation without is ceaſed.

32. Why the Flaſh of a Cannon is ſeen before the Sound is heard.

32. Becauſe the trembling Motion of the Air in which Sound conſiſts, is communicated gradually, ſo that it affects thoſe Parts which are near the ſounding Body ſooner than thoſe that are further off, the Sound muſt neceſſarily take up ſome time in going along: And ſo we find by Experience, that if a Cannon be diſcharged at two or three Miles diſtance from us, we ſee the Flaſh ſome time before we hear the Noiſe.

33. Why the Sound grows weaker, the further we are diſtant from the ſounding Body.

33. And becauſe the Motion which is impreſſed by the ſounding Body upon the Air cloſe by it, is tranſferred from one Part of the Air to another ſucceſſively, and always paſſes from a leſs Quantity to a greater, in proportion to its Diſtance from the ſounding Body; therefore near the ſounding Body, there muſt always be more Motion in a given Quantity of Air, than there is at a greater Diſtance; ſo that the Sound ought to grow weaker as it is further from the ſounding Body.

34. The

34. That Sound going along with the Wind, ought to be heard ſooner than when againſt it.

34. The Propagation of Sound may very well be [1] compared with Circles made in the Water, by throwing a Stone into it. And as thoſe which are made in a running Stream, extend themſelves further towards the lower than towards the upper Part of the River, becauſe the whole Water in which they are formed carries them intire that Way: So likewiſe may we conceive, that if the Wind carries the Air towards one certain Place, the trembling Motion in which Sound conſiſts, will ſooner go this Way than the contrary. Thus we find by Experience, that we hear the Sound of a Cannon, and in general all other Sounds, [2] ſooner with the Wind than againſt it. And it may happen, that the Air may be moved ſo quick, that its Parts may flee from us as faſt as the Sound goes, and ſo we may not hear it at all.

35. How an Echo is made.

35. Becauſe Sound is propagated every Way, as it were from the Center to the Superficies of a Sphere, it may ſo happen, that the Parts of the Air which would communicate their Motion to ſuch as are at a greater Diſtance, may meet ſome hard Body which they cannot ſhake; and this may cauſe them ſome Way to be reflected back again, and make them communicate their Motion again to thoſe Parts from which they received it, and theſe to others; ſo that there will be a new Trembling of the Air inſtead of that which began firſt, and hath already ceaſed for ſome Time: Conſequently we may hear again the ſame Sound which we heard at firſt; and this redoubled Sound is what we call an *Echo*.

36. How an Echo may repeat Words ſpoken ſeveral times.

36. If the Sound meets with ſeveral Bodies at different Diſtances, which are capable of reflecting it back again; if that which returns from the moſt diſtant Place ſtrikes upon the Ear, after the Impreſſion of the former is

1. *Compared with Circles made in the Water*) If the Water be put in Motion, by throwing in a Stone, or by moving our Finger or a Stick backward and forward in it, the Waves will immediately ſurround our Finger; and if during the Agitation it be carried ſtreight forward towards any Part without turning it round, yet theſe Waves, as if they were concentrick Circles, will be equally propagated every Way; which Compariſon does very properly ſhow us, that the tremulous Motion of the Air ought to be propagated not only the ſame way that every one of the Particles of the ſounding Body, ſuch as the Strings of a Violin, are agitated; but alſo to be propagated in a Circle all Ways from the ſounding Body as the common Center.

2. *Sooner with the Wind than againſt it*) The Gentlemen at *Florence* thought they had found by certain Experiments, that Sound is propagated with the ſame Celerity againſt the Wind, as with it, though much more faint. *Exper. Acad. del Cimento, p.* 140. But the induſtrious Mr. *Derham* found it otherwiſe in Experiments made at a much greater diſtance. See *the Philoſophical Tranſactions, Numb.* 313.

quite

quite gone off, it must in its Turn produce a new Sensation of Sound. Whence it is evident, that we may meet with *Echo's* which repeat the same Word several times over.

37. Why he which speaks, does not always hear the Sound of the Echo.

37. According to the Inclination with which the Air strikes upon the Bodies which reflect the Sound, ought the Reflection to be on the one Side or on the other, which is the Reason why there are some *Echo's* where he who speaks does not hear the Words that are repeated, when others who are at some Distance from him can hear them repeated distinctly.

38. What the different Species of Sound consist in.

38. As to the Difference of Sounds that we meet with, which constitutes the different Species of them, as *Flats* and *Sharps*; the musical Instruments sufficiently show us, that they consist in the different Motion both of the sounding Body, and of the Air which is agitated by it. For the more the Strings of a Lute are *strained*, the *sharper* the Sound is; and on the contrary, the *looser* the Strings are, the more *flat* is the Sound. Now it is certain, that the more a String is stretched, the swifter and more frequent is the Motion which it impresses on the Air: whence it follows, that *a sharp Sound* consists in the *Quickness and in the sudden Reiteration of the Motion upon which the Sound depends*, and a *flat Sound* consists in the *Slowness*.

39. How several Sounds may be heard together.

39. When two sounding Bodies strike upon the Air at the same time, they must impress such a Motion upon it, as is compounded of the two Motions which would be caused, if they acted upon it separately; and consequently the Air ought to put the *Organ* of Hearing into such a Sort of trembling Motion, as may raise a Sensation composed of each of the Sensations which the Bodies would raise separately.

40. What Concords consist in.

40. And if the Motion of these two sounding Bodies do so exactly agree, that the Tremblings which they cause in the Air in a given Time are commensurable, that is, at the same time that the one strikes the Air, the other strikes it also, or at least, that they strike together every second or third Stroke; then the Ear will be so uniformly struck upon, and in such Measure, that it will perceive the Distance, and be pleased with the Cadence; and in the Strokes being thus commensurable very probably consists those *Concords* which Musicians call *an Unison and Octave, a Fifth and a Third.*

41. On

41. On the contrary, if the Tremblings impreſſed on the Air by the Sounding Bodies be incommenſurable, that is, if they do not agree in Time nor ſtrike together; we muſt perceive the Inequality of the Sound; and becauſe they do not move the Ear uniformly, they cannot produce any Harmony; and in the Strokes being thus incommenſurable, conſiſts very probably the *Tones* which Muſicians call *Diſcords*. 41. *Why ſome Sounds are Diſcords.*

42. From what has been ſaid concerning the Motion impreſſed on the Air by ſounding Bodies, ſome Perſons perhaps may be apt to think that thoſe impreſſed by the Strings of a Lute are not equal; but quicker at firſt, and ſlower as the Motion ceaſes; but it is not very difficult to ſhow that the contrary is true, if we obſerve, that the Motion of the String when it almoſt ceaſes to be agitated, may be made up by the Shortneſs of the Way that it has to go: So that it takes up neither more nor leſs Time in making its firſt and longeſt Vibrations, than it does in making its laſt and ſhorteſt. 42. *That the laſt Vibrations of the String of a Lute do not take up more Time than the firſt.*

43. There muſt indeed be ſome Pains requiſite to prove the Truth of this by Experiments: For it is impoſſible to do it by the Strings of a Lute, becauſe of the ſmall Time that they take to make ſeveral hundred Vibrations in. But becauſe the Motion we are ſpeaking of is very like *that of a Weight hanging in the Air at the End of a String*, we may imagine, that what we obſerved of the Motion of the one, may be equally applied to the other: Now we find by Experience, that if this Weight be drawn from the Perpendicular, and then let go, ſo as it may ſwing freely, all the Vibrations till it ceaſes to move at all, will be made in the ſame Time. For if we will be at the Trouble to count how many Pulſes of the Artery there are in the firſt twenty Vibrations ſuppoſe, we ſhall find as many in the twenty following Ones, or in any other Twenty, which you will: Now from this ſingle Experiment we may conclude that every Vibration of the String of an Inſtrument is made in the ſame Time, and that the Laſt take up no more than the Firſt. And becauſe this Experiment is very eaſy to make, and is a curious one, and may ſerve as a Principle from whence many important Concluſions in *Muſick* may be drawn; it is worth any one's while to be at the Pains to obſerve the Motions of theſe Pendulums, and to put ſeveral of them in Motion together. For we ſhall then ſee, that thoſe which are of an equal Length, and alike in every other reſpect, will perform their Vibrations in the ſame Time; and that thoſe which are of different Lengths, require different Times, *viz.* the Shorter, 43. *Of the Motion of Pendulums.*

the less Time, so that their Vibrations will be to each other [1] in a reciprocal Proportion of the Square Root of their Lengths; and thus what we have said of the commensurability of Sounds, and the Concords of Musick, is confirmed.

44. *Whence different Sorts of Voices arise, and why the Voices of Children are generally sharper than those of grown People.*

44. From hence we may also clearly apprehend how different Sorts of Voices are made, and why the same Mouth may cause by turns a sharp and a flat Sound. The Reason of which is, that the *Epiglottis* which is placed at the End of the Pipe through which we breath, and which opens to give a Passage for the Air in order to form the Voice, may be lifted up and let down at pleasure, that is, so as sometimes to be altogether and from its Roots open, or shut, and sometimes in Part only. Now that which can be lifted up in such a manner as this, by Turns, and as it were with a trembling Motion, to let the Air out with the same sort of Motion, resembles a *Pendulum*; whence it follows, that the Tremblings of the Voice must be so much the quicker, the less the *Epiglottis* which regulates the Motion, is lifted up, and on the contrary, they are the slowest that can be, when the *Epiglottis* is at liberty to lift it self quite up. Upon this Flexileness of the *Epiglottis* depends all the Variety of Tones of the Voice; for the Air which comes out of the Lungs being differently agitated according to the different Position of the *Epiglottis*, impresses the Motion it received as it came out, upon the external Air, which striking the Ear differently is the Cause of all that Diversity which we observe in Sounds. And because Children have generally all the Parts of their Bodies proportioned

1. *In a reciprocal Proportion*) Here the *Number* of Vibrations in a given Time are compared with each other. But if the *Times* of the Vibrations be compared together (which is the better Way) then we must say, that the Vibrations are to each other, as the square Roots of their Lengths *directly*. As may be thus demonstrated. We suppose that the Acceleration of heavy Bodies in falling is such, that the Spaces they run through, are as the Squares of their Times (which shall be demonstrated in its proper Place. *See the Notes on Part* II. *Chap.* xxviii. *Art.* 16.) then if we imagine similar Arcs of unequal Circles to consist of an infinite Number of Sides of similar Polygons, and that they are in the same Position with respect to the Earth; then it is evident, that the Square Roots of the Arches, or of the Spaces run through, and for the same Reason, their Radius's or the Length of the Strings, will represent the Times of the Descent of Pendulums; and because the *impetus* or Velocity in ascending; is evidently destroyed equally in the same manner, and in the same time as it was acquired in descending; therefore the whole Vibrations of these Bodies must necessarily have the same Proportion to each other, as the Square Roots of the Lengths of the Strings. *See the Notes on* Part II. *Chap.* xxviii. *Art.* 16.

to their Bigneſs, and conſequently their Epiglottis, leſs than in grown Perſons, therefore the Voice is generally ſharper.

45. And altogether as eaſy is it to account for an Experiment which at firſt Sight has ſurprized a great many Perſons; which is, that if two Strings of the ſame Lute, or of different Lutes that are near one another, be *Uniſons*, we cannot move the one, 1 but the other will ſound alſo, at leaſt it will tremble; whereas it will not tremble at all, if we move any other String near it, which is not a *Concord*. Now the Reaſon of this Experiment is, that the Strings which are *Concords*, are capable of the ſame Vibrations; ſo that the Air which is put in Motion by the one, can very conveniently communicate its Vibrations to the other; which cannot be in two Strings that are not *Uniſons*; for there is no Agreement in them, becauſe the Air which is put in Motion by the one, does not find the other at all diſpoſed to receive its Motion; and every Stroke, except the Firſt, is out of Time, ſo that by not agreeing they deſtroy each other's Motion.

45. The Reaſon of the Sympathy of Strings that are Concords.

46. This Experiment has raiſed the Admiration of many Perſons for a long time, and ſome have undertaken to account for it, by ſaying, that there is a Sympathy between the two Strings; but, beſide that this is only a Way of ſpeaking, we may obſerve, that the Diſpoſition which a Body has to move, when the Air is ſhaken by another Body, 2 is to be found in other Things as well as in the Strings of a Lute, or other Muſical Inſtrument: This I have experienced in the late Wars, when I have obſerved the Glaſs-Windows to tremble very ſenſibly upon the beating of a certain Drum, and at the ſame time would not tremble at all upon the beating of others which were much louder.

46. The ſame Sympathy is to be found in other Bodies.

1. *But the other will ſound alſo*) So likewiſe if two Glaſſes, by putting in a proper Quantity of Water, be made Uniſons; the preſſing our Finger hard upon the Edge and moving it round either of them, will make the Water in the other curl, and dance about.

2. *Is to be found in other Things*) Thus Mr. *Boyle* relates concerning a ſick Man that had his Left Hand cut off; upon the diſcharging of Cannons, he thought himſelf almoſt ſhattered and torn to pieces; and of another, that upon ſcraping a piece of Iron with a knife, he could not hold his Water; and of a Third, that upon tearing thick Paper his Gums would bleed. *See his Effect of languid Motion.*

47. What is the Cause of that shivering which we feel upon hearing a Trumpet.

47. To these Sort of Motions, I conceive we may ascribe the Cause of a certain *Shivering*, which we sometimes feel all over our Body, and which reaches even to our very Heart, when we hear the Sound of a Trumpet, or such kind of Instrument; For it may be that the Blood is so disposed, as to yield easily to the trembling of the Air.

48. How we render our selves attentive, so as to hear Sounds distinctly.

48. And because the Membrane of the Ear, which is moved by the Agitation of the external Air, the different shaking of which causes different Motions in the Capillaments of the Nerves of the Ear, is something like the Parchment of a Drum (and is therefore by some called the *Drum* of the Ear;) I am of Opinion, that it is capable of being more or less shaked, according as it is more or less stretched. Wherefore I can easily persuade my self, that we sometimes stretch or loosen it, in order to receive the Impression of the Sound more sensibly, and to make it the better agree with the Motion of the external Air: So that Attention consists in nothing else but in a due stretching or loosening this Membrane; and keeping it in that Position in which it will best receive the Impression and Motion which the Sound gives to the external Air.

CHAP. XXVII.

Of Light and Colours, and of Transparency, and Opakeness.

1. The first Sense of the Words Light and Colours.

IF in any Thing Exactness be required in the Meaning of Words, in order not to be surprized by any Equivocation, it is principally in this of *Light* and *Colours*, which are commonly used to signify very different Things, and generally confounded by most Men. First then it is to be observed; that as we have given the Name *Pain* to the Sensation, which is raised in us by a Needle when it pricks us; so likewise have we given the Name *Light* to that Sensation which we have, upon looking on the Sun or a Flame, and that of *Colour* to the Sensation raised in us by diverse Objects which we call coloured; thus in particular, we give the Names of a *White Colour* and a *Green Colour* to the Sensations which *Snow* or *Grass* usually produce in us.

2. Se-

2. Secondly, By these Words *Light* and *Colour*, we also understand, *that* on the Part of the external Objects which is the Cause of exciting in us the forementioned Sensations: Thus by the *Light* of the Flame, we mean something, I know not what, which occasions the Sensation of *Light* to be excited in us; and by the *Whiteness* of the Snow, we understand some other Thing, I know not what, that is the Occasion of our having the Sensation of *Whiteness*. *2. Another Sense of the Words Light and Colour.*

3. And because the Objects which we call luminous, such as the Sun or a Flame, do not affect our Eyes immediately, but act by the Interposition of some intervening Bodies, such as Air or Water or Glass; yet that which is impressed on these Mediums, whatever it be, is called *Light* also, but *Secondary* or *Derivative*; to distinguish it from that which is in the luminous Objects which is called *original* or *innate*. *3. A third Sense of the Word Light.*

4. We call those Bodies *Transparent*, through which luminous Bodies act upon our Eyes to raise the Sensation of Light, and through which we can also see Colours. And we call those Bodies *Opake* which interrupt the Action of luminous or coloured Bodies, or through which we cannot see either Light or Colours. *4. The Meaning of the Words Transparent and Opake.*

5. I do not pretend to declare what *Light* and *Colours* are in the first Sense of the Words, but leave it to every one to make them clear to himself by his own Experience; for I think it as impossible to give another Person a true Notion of that particular Sensation that we have of Colours, as it is to give it to one that is born blind. *5. That the Sensation of Light or Colour cannot be described.*

6. However, I may venture to affirm, that as it often happens that the same Food may at the same time raise different Tastes in two different Persons; so it may also happen, that two Persons looking in the same manner upon the same Object, may have very different Sensations; and I am the more perswaded of this, because I have experienced it in a particular manner my self. For when I had once quite tired and weakned my right Eye by looking intently for above twelve Hours together through a perspective Glass on a Battle betwixt two Armies, within a League of me; I found my Sight so affected afterwards, that when I looked upon Yellow Objects with my right Eye, they did not appear to me as they used to do, nor as they now do to my left Eye: And, which is very remarkable, I do not find the same Difference in all Colours but only in some; as for in- *6. That one and the same visible Object does not necessarily raise the same Sensation in two different Persons.*

ſtance in Green, which appears to me to come near to a Blue, when I look on it with my right Eye. This Experience makes me believe, that there may be ſome Men born with that Diſpoſition, which I at preſent have in one of my Eyes, and which may continue all their Lives, and perhaps there are others whoſe Eyes are of the ſame Diſpoſition with my other Eye. However, it is impoſſible, either for themſelves or any other Perſons to perceive it, becauſe every Body accuſtom themſelves to call the Senſation which a certain Object produces in him, by that Name which it uſually goes by; which yet being common to the different Senſations that every one may poſſibly have, is not the leſs ambiguous.

7. Ariſtotle's *Opinion about Light.*

7. Before I come to that Enquiry which I deſign, *viz.* what Light is, and what the *Colour* of Objects is, which is the principal Deſign of this Diſcourſe; I obſerve, that *Ariſtotle* has treated of the ſame Subject, in the 7th Chapter of his Second Book *Concerning the Soul*; where after having ſaid, that *Colours* depend upon *Light* in order to their being ſeen, he concludes, that theſe two Qualities ought to be explained together. And in order to determine what *Light* is, he ſuppoſes that ſome Bodies are *tranſparent*, ſuch as Air, Water, Ice, Glaſs, and ſuch like. And becauſe we cannot ſee through any of theſe Bodies in the Night, he ſays, that then *they are in Power only tranſparent*, and that in the Day-time *they become actually tranſparent*; And becauſe it is *Light* alone that can *bring this Power into Act*, he concludes, that *Light is the Act of a tranſparent Body as tranſparent.*

8. *His Opinion about Colours.*

8. As to *Colour*, he obſerves, that ſince the Object in which it is, does not apply it ſelf immediately to our Eyes, in order to raiſe any Senſation in us, it muſt firſt move the *Medium* which is betwixt *that* and us; and becauſe it cannot be perceived through Opake Bodies, nor can it be ſeen through thoſe that are *only tranſparent in Power*, he concludes, that *Colour is that which moves Bodies which are actually tranſparent.*

9. *That he has not ſufficiently explained what Light and Colours are.*

9. Though *Ariſtotle* in the forecited Chapter, has not ſearched this Matter to the Bottom, yet he affirms, that he has ſufficiently explained what *Light*, and *Colour*, and *Tranſparency* are, and imploys almoſt all the remaining Part of his Diſcourſe, in refuting the Opinions of ſome Philoſophers that were before him. However he adds, that *Light* is not Fire, nor a Body proceeding from a Luminous Body, and paſſing through a tranſparent one; but only the *Preſence of Fire, or any other luminous Body* with

with the transparent Body. But upon confidering this Opinion, I fee no reafon to be fully fatisfied with it, as if it could not be carried any further than *Ariftotle* has done, or at leaft, that it cannot be more diftinctly explained. For it is certain, we are ftill at a lofs to find out more particularly what the Nature of tranfparent Bodies, and alfo what the Nature of luminous Bodies is; and further how the *Prefence of the Latter operates on the other, to bring its Power into Act*; and laft of all, what *that* is which moves a Body that is *actually tranfparent*.

10. This fome of the Commentators upon *Ariftotle* have acknowledged; and though they might have had fome Light from what he has faid in his Problems, and particularly from [1] the 61ft of the *Eleventh Section*; yet they have either overlook'd what he has faid in this Place, or at leaft not rightly underftanding him, they have advanced fomething which it does not appear that *Ariftotle* ever thought of, *viz.* that *Light* and *Colours* in the Objects which we call luminous or coloured, are Qualities exactly like thofe Senfations which they occafion in us and (as fome of them contend) they arife alfo from a Mixture of Hot and Cold, of Dry and Moift. And for Proof of this (befides their thinking, that they have *Ariftotle* on their Side) they affirm, that it would be impoffible for luminous or coloured Bodies to caufe thofe Senfations in us which we feel, if there were not in them fomething very like what they caufe us to feel; for, fay they, nothing can give what it has not.

10. What the Opinion of his Followers is concerning Light and Colours.

11. But, befides that *Ariftotle* has faid nothing pofitively concerning what they have advanced, Authority ftands for nothing, when we are inquiring after Reafons only. And as to what they alledge, it will appear to be only a mere Sophifm, if we reflect ever fo little upon the Pain which we feel when we are pricked by a Needle; for this fhows us, that it is not at all impoffible for an Object to be able to excite in us a Senfation which it felf has nothing of. And this is ftill further confirmed from hence, that two Men may fee the fame Object differently, as was before obferved, I my felf feeing Yellow differently with my two Eyes.

11. That they have not proved what they affert.

1, *The 61ft of the Eleventh Section*) Where, after having propofed this Queftion. *Why we cannot fee through an Opake Body.* He argues very much for the Propagation of Light in ftreight Lines. See *the Notes on the latter Part of the 15 Art. of this Chapter.*

12. *That it is not true.* 12. But that which most evidently shows, that it is not at all necessary there should be any Resemblance between the Quality of the Object, and the Sensation it excites, is this; that we certainly have very strong Sensations of Red, and Yellow, and Blue, and all other Sorts of Colours, upon looking through a Triangular Glass *Prism*, in which no one ever suspected that there was any Thing like the Sensation which it raises in us.

13. *The Absurdity of the Opinion of some of the* Aristotelians. 13. That which others of them say concerning the Original of Colours is still more absurd. For what Connexion is there betwixt the *Idea's* we have of Hot and Cold, Dry and Moist, and those which they suppose us to have of Colours: If what they say were true, it would from hence follow, that the same Object ought to have as much Variety of Appearances to the Eyes, as it raises different Sensations to the Touch; which does not agree with Experience: On the contrary, there are some Bodies, such as polished Steel, and Lobsters, which when heated by the Fire, acquire a certain Colour; but when made cold by dipping them in Water, they do not alter their Colour.

14. *A Comparison of the Sensation of Light with that of Pain.* 14. Leaving therefore the Opinion of *Aristotle* and his Followers, concerning Light and Colours, let us now consider what Part we are to take upon this Subject. And First, Since we have no Reason to say, that the *Light* of luminous Bodies is any Thing else but *the Power which they have to produce in us that very clear and bright Sensation which we have when they are before us*; Why may we not compare this Power with that which a Needle has to cause Pain in us? Since then the Sensation which a Needle raises in us, supposes only that we are sensitive Creatures; and nothing more is required in the Needle but its Figure and Hardness, which are alone sufficient to cause a Division in the Part to which it is applied: So likewise it is reasonable to think, that the Sensation of Light depends upon this, that we are by Nature made capable of this Sort of Sensation; and that there is in the Pores of transparent Bodies, a Matter fine enough to penetrate even Glass, and yet at the same time strong enough to shake the small Capillaments of the Nerves which are at the Bottom of the Eye. Further, as there must be some Agent to push the Needle into us, so likewise must we think, that this Matter is pushed by the luminous Bodies, before it can make any Impression on the *Organ* of Sight.

15. Thus

15. Thus 1 *Original Light* consists *in a certain Motion of the Parts of luminous Bodies* whereby they are capable of pushing every Way the subtil Matter which fills the Pores of transparent Bodies; and *the Essence of secondary or derived Light* consists *in the Disposition or Tendency of this Matter to recede from the Center of the luminous Body in a streight Light.* Whence it is easy to infer, that the Form *15. What our Opinion of Light and Transparency, and Opakeness is.*

1. *Original Light----Secondary or derived Light*) *Original* Light consists intirely in a particular Motion of the Particles of the luminous Body; not whereby they push forward that fictitious Matter which *Cartes* imagined the Pores of transparent Bodies to be filled with; but whereby they shake off some very small Particles from the luminous Body, which are sent forth all Ways with a very great Force: And *Secondary* or *Derivative* Light consists, not in the Disposition, but in the real Motion of those Particles receding every way from the luminous Body in streight Lines with incredible Swiftness. For if Light consisted only in *Pressure*, it ought to be propagated to all Distances in a *Moment of Time*; which it certainly is not (See *the Notes on Art.* 30. *below.*) And it would not be propagated in streight Lines, but it would perpetually run in upon the Shadow. *For Pression or Motion cannot be propagated in a Fluid in right Lines beyond an Obstacle, which stops part of the Motion, but will bend and spread every Way into the quiescent Medium, which lies beyond the Obstacle. Gravity tends downwards, but the Pressure of Water arising from Gravity, tends every way with equal Force, and is propagated as readily, and with as much Force sideways as downwards, and through crooked Passages as through streight ones. The Waves on the Surface of stagnating Water, passing by the sides of a broad Obstacle which stops part of them, bend afterwards, and dilate themselves gradually into the quiet Water behind the Obstacle. The Waves, Pulses or Vibrations of the Air, wherein Sounds consist, bend manifestly, though not so much as the Waves of Water---And Sounds are propagated as readily through crooked Pipes as through streight ones. But Light is never known to follow crooked Passages, nor to bend into the Shadow.* Newt. Opticks pag. 337. Rays of Light therefore must be small Corpuscles sent forth from luminous Bodies with a very great celerity. For such sort of Corpuscles (contrary to the Pression of Motion propagated in a Fluid) ought to be transmitted through uniform Mediums or void Spaces in streight Lines, without bending into the Shadow; as we see the Rays of Light are transmitted.

Concerning that Force by which these Corpuscles are sent forth with such incredible celerity, that they are carried above 7000000 of Miles in a Minute (See *the Notes on Art.* 30. *below.*) the admirable Person before-cited speaks thus. *Those Bodies which are of the same kind and have the same Vertue, the smaller they are, the stronger is their attractive Force in Proportion to their Bigness.* (See the Notes on Chap. xi. Art. 15.) *We find this Force stronger in proportion to their Weight in small Magnets than in larger ones; for the Particles of small Magnets, because they are nearer one another, can the more easily unite their Forces together. Wherefore it is reasonable to expect, that the Rays of Light, since they are the smallest of all Bodies (that we know of) should be found to have the strongest attractive Force of all. How strong this Force is, may be gathered from the following Rule. The Attraction of a Ray of Light, in proportion to the Quantity of Matter it contains, is to the Gravity which any projected Body has, in proportion to the Quantity of Matter contained in it, in a Ratio compounded of the Velocity of the Ray of Light, to the Velocity of the projected Body, and of the Bending or Curvature of the Line which the Ray describes in the Place of Refraction, to the Bending or Curvature of the Line which the projected Body describes; viz. if the Inclination of the Ray to the refracting Superficies*

Form of a *Transparent Body* consists [1] *in the Streightness of its Pores*, or rather, *that they cross each other all ways without any Interruption*, and on the other hand, a Body is opake, because *none of its Pores are streight, or if they be, they are not penetrable quite through, and all ways.*

16. I

perficies, be the same as that of the projected Body to the Horizon. And from this Proportion I collect, that the Attraction of the Rays of Light is more than 1000000000000000 *times greater than the Gravity of Bodies on the Superficies of the Earth, in proportion to the Quantity of Matter contained in them;* viz. *if Light takes up about seven or eight Minutes in coming from the Sun to the Earth.*--- Now, *as in Algebra, where affirmative Quantities vanish and cease, there Negative ones begin; so in Mechanicks, where Attraction ceases, there a repulsive Vertue ought to succeed.*--- Therefore *a Ray, as soon as it is shaken off from a shining Body, by the vibrating Motion of the Parts of the Body, and gets beyond the Reach of Attraction, is driven away with exceeding great Velocity.* Opticks pag. 370.

1. *In the streightness of its Pores*) Thus *Aristotle* clearly expresses himself. *The Sight will not penetrate solid Bodies, because it can go only through a streight Passage (this the Rays of Sun are an Evidence of, and also our not seeing any Objects but what are right before us; (when therefore the direct Progress of the Sight is hindred by the Pores not being all streight, it cannot pass through. But the Sight will pass through fluid Bodies, because the Pores are small and streight; so that it is not hindred from going through them. Wherefore Glass is transparent though it be very thick; but a piece of Wood is not transparent, though it be very thin, because the Pores of the former are regular, and those of the latter irregular. Nor does their being large signify any-thing if they be not streight; neither are rarer Bodies the more transparent, unless their Pores are so disposed as to admit of a Passage.* Prob. 61. Sect. 11. And indeed that streight Pores, or rather such as cross one another every way from all Sides, are necessary to a Body's being transparent cannot be doubted: But how it can be, that not only Glass and Diamonds, but also Water, whose Parts are so easy to be moved should have its Pores streight, and easy to pass through from all Sides; and all Ways, and yet at the same time, the thinnest Paper or even Leaf-Gold, *for want* of such Pores, should exclude the Rays of Light; is not easy to be conceiv'd. Wherefore we must seek for another Cause of *Opakeness*.

We must know then, that all Bodies whatsoever, have in them much fewer Parts, and much more Pores or void Spaces, than is requisite for the greatest Number of Rays of Light to find a free and open Passage in streight Lines all ways without running upon the Parts. For since Water is nineteen times lighter, that is, rarer than Gold, and Gold it self is so rare, that it will very easily, without making any Resistance, suffer the Magnetick Effluvia to pass through it, and will easily admit Quicksilver into its Pores, and will also let Water go through it, that is, it has more Pores than solid Parts; consequently Water will have above forty times as many Pores as solid Parts. And indeed you may think, Gold and Water, and all other Bodies (with great Probability) as much rarer still as you please. *For if we conceive the Particles of Bodies to be so disposed amongst themselves, that the Intervals, or empty Spaces between them, may be equal in Magnitude to them all: and that these Particles may be composed of other Particles much smaller, which have as much empty Space between them, as equals all the Magnitudes of these smaller Particles: And that in like manner, these smaller Particles are again composed of others much smaller; all which together, are equal to all the Pores or empty Spaces between them, and so on perpetually, till you come to solid Particles, such as have no Pores or empty Spaces within them. And if in any gross Body there be, for instance, three such degrees of Particles, the least of which are solid; this Body will have* seven times *more Pores than solid Parts, But if there be*

four

16. I doubt not but that this Opinion will be esteemed a Conjecture only. But if it shall afterwards be made appear to have in it all the Marks of Truth, and that all the Properties of Light can be deduced from it: I hope that *That* which at first looks like a Conjecture will be then received for a very certain and manifest Truth. *16. A Confirmation of this Conjecture.*

17. And first, that we are fitted by Nature to perceive what we call Light, though there were nothing that bore any Resemblance to it without us, we have a very convincing Experience: For if, when it is the Darkest that can be, we rub our Eyes in one particular manner, or if by chance we receive a very hard Blow upon them, so that the internal Parts of the Eyes are very much shaken by the Blow, we see Light, and very bright Sparks, which cease as soon as the Motion ceases. *17. That we are fitted to perceive Light.*

for such degrees of Particles, the least of which are solid, the Body will have fifteen times *more Pores than solid Parts. If there be five Degrees, the Body will have* one and thirty times *more Pores than Parts. If six Degrees, the Body will have* Sixty and three times *more Pores than solid Parts, and so on perpetually.* Newt. Opt. p. 243.

The Reason therefore why some Bodies are *Opake*, is not the want of Pores which are passable on every Side in streight Lines; but either the unequal Density of the Parts, or the Largeness of the Pores, either filled with other sort of Matter, or else empty; by which means the Rays of light in passing through, are perpetually bent backward and forward by innumerable Reflections and Refractions, till at last they hit upon the Parts themselves of the Body (*See the Notes below on Art. 35.*) and so are wholly extinguished and lost. Hence it is, that Cork, Paper, Wood, *&c.* are Opake; and Glass, Diamonds, *&c.* transparent. For in the Confines of Parts that are alike, and of equal Density, as the Parts of Glass, Water, and Diamonds are, by reason of the equal Attraction on all Sides, there is no Reflexion or Refraction; and therefore the Rays of Light which enter the first Superficies of these Bodies easily go on (except such as chance to fall upon the solid Parts, and are extinguished. *See the Notes on Art. 35. below*) in a right Line through the whole Body. But in the Confines of Parts which are very unequal in Density, such as the Parts of Wood or Paper, compared with each other, or with the Air, or empty Space in the larger Pores of them, the greatest Reflexions or Refractions are made, because of the unequal Attraction; therefore the Rays can by no means pass through such Bodies; but are perpetually bent backward and forward, and at last lost. *That this Discontinuity of Parts is the principal Cause of the Opacity of Bodies, will appear by considering that Opake Substances become transparent, by filling up their Pores with any Substance of equal, or almost equal Density with their Parts. Thus Paper dipp'd in Water or Oil, the* Oculus Mundi Stone *steeped in Water, Linnen-Cloth oiled or varnished, and many other Substances soaked in such Liquors as will intimately pervade the little Pores, become by that means more transparent than otherwise; so, on the contrary, the most transparent Substances may by evacuating their Pores, or separating their Parts be rendered sufficiently opake, as Salts or wet Paper, or the* Oculus Mundi *Stone, by being dried, Horn by being scraped, Glass by being reduced to Powder, or otherwise flawed; --and Water by being formed into many small Bubbles--become Opake.* Newt. Opt. p. 224.

18. Fur-

18. That there is such a Thing as subtil Matter, was proved before.

18. Further, That there is such a Thing as subtil Matter which penetrates the Pores of transparent Bodies, the Disposition of which to recede from the Center of the luminous Body in streight Lines, may here be called *secondary* or *derived* Light, has been sufficiently proved before, when we shewed the Necessity of the second Element; and we may venture to affirm, that none of those Things would come to pass without it, which we have before observed to come to pass, when we explained those Motions which are usually ascribed to the *Fear of a Vacuum.*

19. That luminous Bodies push this Matter all Ways; and what it is that Flame consists in.

19. Nothing further remains, but to show that luminous Bodies do actually push this Matter every Way; which they will be found to do, if it be true, that the Parts are very small, and very much agitated. Let us then examine all the luminous Bodies that we know, and see if the Parts of which they are composed, be not as small, and as much agitated as we suppose. And to begin with *Flame.* It has been already so plainly demonstrated, that it is composed of Parts very small, and which move with the greatest Celerity, that it is superfluous to say any more about it.

20. Whence it is that Sparks arise upon striking or rubbing two hard Bodies against each other.

20. We see also, that there arises very bright Sparks upon striking a *Flint* against *Steel*, or *two Flints* against each other, or an *Indian Cane* against a *common one*, or by stroking the *Back of a Cat* in the Dark, when the Weather is dry and cold, [1] and in a Multitude of other Things. The Cause of all which, is only this, that some of the Particles of these Bodies being entangled between others, when they are struck, acquire in flying off, a Motion like that of Flame, by which they in like manner push forward the small Globules of the second Element.

21. The Cause of the shining of rotten Wood, and of some Fishes that are corrupted.

21. There is some sort of *rotten Wood,* and of *Fishes, when they begin to be corrupted,* which shine very bright. Now a Body cannot putrify or be corrupted, but by the Motion of its Parts, some of which fly off (as is evident in rotten Wood, from the Largeness of its Pores, and from its Lightness, which render it different from what it was before; as a Coal, and the Wood out of which it is made differ from each other.) We must own therefore,

1. *And in a Multitude of other Things*) Thus likewise *Amber* rubbed very hard in the Dark; *Quicksilver* shaken in a *Vacuum*; and a *Glass* out of which the Air is exhausted, if it be turned round very quick and rubbed, will shine bright, not by impelling or pressing upon the Particles of the second Element, for there is no such Thing; but by sending forth small Particles which are the very Light it self.

that the Motion of the Parts which we suppose in luminous Bodies, [1] is to be found here also.

12. It is not so easy to tell certainly, what sort of Motion that is, which makes some *Worms* and *Flies* to shine in the Dark: However it is very probable, that some sort of Matter is exhaled out of these Insects, like the Sweat of other Animals, and that this pushes the Matter of the second Element; and this is confirmed from hence, that they cease to shine as soon as they are dead. *22. Of the Light of Glow-worms.*

23. The *Sun* and the *Stars* are the most luminous Bodies of any that we know; but by reason of their great Distance, it is impossible to make appear by any Experiments taken near them, that all their Parts are in Motion; all that we can affirm, is only this, that we do not observe any Thing to the contrary: And since they produce the same Effects in us, that Flame does, we ought to think, that they resemble it in that by which these Effects are produced, *viz.* in the Motion of their Parts. *23. Of the Light of the Sun and Stars.*

24. If it were true, what they say of a *Carbuncle* and a *Diamond*, *viz.* that they shine in the Dark; I should freely own, that I am mistaken in all that I have said about Light; for there is no Probability, that Bodies so hard, should be composed of Parts which separately are in any Sort of Agitation. But it is certain, that these are only idle Stories, told without any Proof, and received by credulous Persons, for I have often times experienced the contrary my self. *24. That Naturalists are deceived in what they relate of a Carbuncle and a Diamond.*

25. Tis true indeed, that a Diamond shines very bright in a darkish Place; but the Reason of this is, because it is so cut, that the Sides reflect all the Light which they receive towards the same Part, as shall be more fully explained * afterwards, when we come to treat of the Refraction of Light. *25. What the Brightness of a Diamond consists in.* * *Sect. 46.*

26. We have lately had an Account from *England*, that [2] some Diamonds rubbed in the Dark, have shined so bright for a short time, that a Word or two might be read by Light of them. I have not observed this in any *26. Of the Light of a Diamond, when it is rubbed.*

1. *Is to be found here also.*) The famous Mr. *Boyle* made an Experiment of this Matter, which is very well worth taking notice of. He put a piece of rotten Wood into the Air Pump, which was in a Manner extinguished and ceased to shine, when the Air was exhausted: but upon letting the Air in again, it seemed to be new lighted, and shined as before. See the *Philosophical Transact. Numb.* 31. For this was true Flame, and like all other Flame cannot be preserved without Air.

2. *Some Diamonds rubbed in the Dark*) See Art. 20. above.

Diamonds

Diamonds that I have tried; however it may be true, without contradicting any Thing that I have hitherto wrote. For the Rubbing may raife fome Agitation, if not in the Parts of the Diamond, yet at leaft in fome Matter contained in the Pores of it, which continuing in Motion in the fame manner as the Flame in the Pores of a burning Coal, may for fome time pufh the fecond Element which is all round it, and difpofe it to raife a fmall Senfation of Light.

27. *Of the Boulogn-Stone.* 27. Though we have no Jewels which fhine in the Dark, yet we have a Stone that is truly luminous: This Stone was accidentally found by an *Italian Chymift* near *Boulogn* in a hollow Place caufed by a Torrent. After having put it into a Fire for fix Hours, he took it out, and let it cool; and when it had been expofed to the Light of the Air for fome time, upon carrying it afterwards into the Dark, he firft perceived it to look like a Fire-Coal covered over with a few Afhes. I have feen fome fhine near half a quarter of an Hour, after which their Light vanifhed, but by expofing them to the Light of the Air for a fhort time, we could make them fhine again when we pleafed.

28. *The Reafon of this Stone's fhining.* 28. The Reafon hereof very probably is, that the Fire has made this Stone extremely porous, fo that among the Parts which are almoft wholly disjoined from each other, there may be fome 1 fo eafy to be put in Motion, that the Light of the Air alone is capable of agitating them; and they may be fo difpofed to retain this Motion, that they may keep it after they are removed from amongft the luminous Bodies, which put them in Motion; and this is confirmed from hence, that when this Experiment is often repeated, thefe Parts exhale, and the Stone quite lofes its fhining Quality; which Quality cannot be preferved above four or five Years, though the Stone be carefully fhut up in a Box, where no Light can come at it.

29. *A Confirmation hereof.* 29. For a further Confirmation of what has been faid, we may obferve, that if this Stone be kept too long in the Fire, or though it be kept in it but fix Hours, yet

1. *So eafy to be put in Motion*) In much the fame manner may the *Phofphorus* be accounted for, (the manner of preparing it, is at large explained by the famous Mr. *Boyle*, to whom I refer you,) for it is very probable, that fome fulphureous Parts of the Urine, prepared over a very hot Fire, are fo volatile and eafy to be put in Motion, that they are turned into a kind of Flame, by the Agitation of the groffer, or perhaps of the finer Air.

if

if the Fire be very hot, all the Parts of it which cannot refift the Fire, may be carried off, and then the remaining Parts may be fo heavy, as not to be fhaked by the Light; in which cafe the Stone ought not to fhine, and fo we find by Experience.

30. That Light ought to be propagated in a Moment to all Distances.

30. Having thus fhown the Truth of thofe three Things which comprehend the Whole of our Conjecture, about *Primitive* or *Original Light*, concerning what they call *fecondary* or *derivative Light*, we obferve firft; that becaufe it does not confift in the actual Motion of the fubtle Matter which fills the Pores of tranfparent Bodies, but only in the Tendency or Difpofition which this Matter has to Motion; it neceffarily follows, that luminous Bodies, be they never fo diftant, ought to propagate their Force, and [1] to affect our Senfes in a Moment of Time; becaufe the Matter which is pufhed, being extended every way without Interruption, like a very long Stick; the luminous Body cannot pufh forward the neareft Part of it, but at the fame time it muft impell the furtheft Part likewife.

31. A Difficulty about the Action of the Rays of Light.

31. But perhaps fome may think, that this Train of Matter which is extended from one Point of the luminous Body, to a Point of the Object which it illuminates, and which is called *a Ray of Light*, may more properly be compared to a Thread than to a Stick, becaufe its Parts are not fo firmly connected together, as thofe of a Stick are; and fo it may be conceived, that as we can move one end of a Thread, without moving in the leaft the other End, fo the luminous Body may impel the Matter of the fecond Element to which it is applied, without neceffarily continuing that Impreffion to any great diftance. However, if we confider, that the World is full of Matter, and that a Ray of Light is always furrounded by a great many others, which hinder it from bending as a Thread does which is not furrounded by others, we fhall be of Opinion, that every Ray of

1. *To affect our Senfes in a Moment*) It appears now from the Phenomena of *Jupiter's* Satellites, which get into the Shadow of *Jupiter* a little fooner than they ought to do, when the Earth approaches towards *Jupiter*; and on the other hand, come out of the Shadow a little later than they ought to do, when the Earth departs from *Jupiter* (as many eminent Aftronomers have obferved) that Light (which is a real Body) is not propagated in a Moment of Time, but takes up about feven Minutes in coming from the Sun to the Earth, which is about 50000000 of Miles (See *Newt. Opt. p.* 252.) What furprizing Things follow from Lights not being propagated in a Moment, but in a certain Space of Time, You may fee *in the Notes on Part* II. *Ch.* xxv. *Art.* 3.

Light

Light [1] ought to propagate the Force of the luminous Body in the same manner, as if it were as stiff as a Stick.

32. That a Body may propagate its Action thro' an intermediate Liquor.

32. In order to explain what is difficult in this Matter, let us compare this Action of the second Element which transmits Light, to the Action of Water contained in a long thick Tube stopped at the lower End; and then let us consider, that all the small Threads of which this gross Column of Water is composed, do every one in particular press with its whole Weight upon the Bottom; and that if we pour in never so little Oil, it will press upon the Bottom in the same manner as if we had poured it upon a stiff Stick.

33. That to propagate this Action it is not necessary the Liquor should be contained in any Vessel.

33. If this Comparison does not seem just, because in this Instance the Water is contained in a Vessel; take another: Suppose the Surface of the Earth, instead of being unequal and rough as it is now, were round and smooth, and imagine it to be covered all over with Water to a certain Height; then would every Point of the Earth's Surface be pressed upon by the whole Weight of the Thread of Water which correspends to it; now compare the Action of the Rays of Light to the Action of this Water, and you will find, that they are capable of acting in the same manner, as if they were as stiff as a Stick.

34. Why the Action of Light grows weaker, the more distant the luminous Body is.

34. It is true however, and must be granted, that there is some Difference between these two Things: For the Threads of the Water approach nearer and nearer to each other, and tend to the same Center, whereas the Rays of Light go from the Center and spread themselves towards the spherical Superficies which we may conceive all round them: But this Difference will only be of use, to show us the reason of a very remarkable Property of Light; which is, that the Impression of the luminous Body does not come entire to the Object; but is weakened and diminish'd a little, according as it spreads it self, and proportionably to its Distance from the Center of Action. In order to explain this, let us suppose the Tube ABC, which grows wider towards the Top, to be filled with Water as high as DE, and that afterwards with a Syringe we put as much Water in at the End A of this Tube, as will fill the Space AFG, which is of a considerable Height, but of a small Breadth. It is certain, that this Addition of Water, will raise up the Water at HI a little,

Tab. IV. Fig. 3.

[1]. *Ought to propagate the Force)* To propagate it indeed, but not in straight Lines, as Light is really propagated. *See the Notes on Art. 15. above.*

little, but that it will be ſcarce ſenſibly raiſed at DE. Now this explains the Nature of Light perfectly well. For as we cannot ſay that the Water at DE is not raiſed at all, but only that it is raiſed but a very little: So we may conclude, that the further the Rays of Light are diſtant from the luminous Body, the weaker they are; which agrees with Experience.

35. Now as we are certain, that a Body in Motion alters its *Determination* when it meets with another Body that reſiſts it: So likewiſe we may conclude, that Light, when it falls [1] upon the Surface of a ſolid Body ought to be *turned back* or reflected. Thus for Example, if the ſmall Globules which are in the Line CD repreſent the Parts of the ſecond Element compoſing a Ray of Light, which falls upon the ſolid Body AB, its Action ought to be continued towards E, along the Line DE, in ſuch a manner, as that the Angle of *Reflexion* BDE ought to be equal to the Angle of *Incidence* ADC, that is, this Action ought to be propagated in the ſame Lines that the Globule C would deſcribe, if it were alone, and moved in the Line CD: For

35. Why Light meeting with certain Bodies ought to be reflected.

Tab. IV. Fig. 4.

1. *Upon the Surface of a ſolid Body*) The Reflexion of the Rays of Light is cauſed, not by falling upon the Parts themſelves of the reflecting Body, but by a certain Power equally diffuſed all over the Surface of the Body, whereby it acts upon the Ray to attract or repel it, *without immediate Contact*; by which ſame Power in other Circumſtances the Ray is refracted; and by which ſame Power it is at firſt ſent forth from the lucid Body; as the fore-cited admirable Perſon has demonſtrated by many Arguments.

I. Though thoſe Glaſſes which we call plain and poliſhed, do indeed appear to the Eye to have a ſmooth uniform Surface; yet in reality, (ſince poliſhing is nothing elſe but wearing away and breaking the Protuberances of the Glaſs, with Sand, Putty, or Tripoly) their Surfaces are very far from being plain and ſmooth; Now if the Rays of Light were reflected by impinging on the ſolid Parts of the Glaſs, their Reflexions could not be ſo exact and regular, as we find they are; nay, the Rays ought to be diſperſed all Ways, almoſt as much by the beſt poliſhed Glaſs, as by the roughest. *See Newt. Opt. p.* 240.

II. If the red and blue Rays which are ſeparated by a Priſm (*the manner of doing which, See in the Notes on Art.* 65. *below.*) be all of them caſt on a ſecond Priſm, in ſuch manner, that they are all alike incident upon it; the ſecond Priſm may be ſo inclined to the incident Rays, that thoſe which are of a blue Colour, ſhall be all reflected by it, and yet thoſe of a red Colour (though falling with the ſame Obliquity) pretty copiouſly tranſmitted. Now if the Reflexion be cauſed by the impinging of the Rays upon the Parts of the Glaſs; how comes it to paſs, that when all the Rays fall with the ſame Obliquity, the Blue ſhould wholly impinge on the ſolid Parts, ſo as to be all reflected, and yet the red find Pores enough in the ſame Place to be in a great meaſure tranſmitted? Pag. 239.

III. Where two Glaſſes touch one another, there is no ſenſible Reflexion, and yet there is no Reaſon why the Rays ſhould not impinge on the Parts of Glaſs as much when contiguous to other Glaſs, as when contiguous to Air. *Ibid.*

IV. When the Top of a Water-bubble, made by the working up of Soap and Water, by the continual ſub-

For it is evident, that the Globule D ought to have a Tendency, and to be diſpoſed to go where it would really go, *if its Power were put into act.* And ſince this Globule, upon meeting with the Body AB, would neither go towards G, nor towards H, but only towards F; it muſt be allowed, that it is the Globule F only which is impelled

ſubſiding and exhaling of the Water grows very thin; there is no manifeſt Reflexion, not only at the leaſt Thickneſſes, but alſo at many other Thickneſſes of the Bubble, which are continually greater and greater; and yet in the Superficies of the thinned Body, where it is of any one Thickneſs there are as many ſolid Parts for the Rays to impinge on as where it is of any other Thickneſs. *Ibid.*

V. If the red and blue Rays ſeparated by a Priſm (*the manner of doing which, as was ſaid before, you may ſee in the Notes on Art. 65. below*) be afterward caſt diſtinctly and ſucceſſively upon a thin Plate of any tranſparent Matter, whoſe Thickneſſes grow continually greater and greater (ſuch as a Plate of Air contained between a plain Glaſs, and a Glaſs that is a little gibbous, ſuch as the Object-Glaſs of a long Teleſcope) this Plate in the *very ſame* Part of it will reflect all the Rays that are of one Colour, and tranſmit all thoſe that are of another Colour; in *different* Parts of it, it will tranſmit Rays of the ſame Colour at one Thickneſs, and reflect them at another, and this by innumerable Fitts. Now it is not any way to be imagined or conceived, that it can ſo happen by chance, that in the *very ſame* Part of the Plate, and with the very ſame Obliquity of the Rays, all the Rays that are of one Colour ſhould impinge upon the ſolid Parts, and all the Rays that are of another Colour ſhould hit upon the Pores only; and that in *different* Parts of the Plate, in one Place the blue Rays ſhould all impinge upon the Parts of the Body, and the red Rays run all into the Pores; and in another Place where the Plate is a little thicker or a little thinner, on the contrary the blue Rays only ſhould run all into the Pores, and all the red Rays impinge upon the Parts. *Pag.* 240.

VI. In the Paſſage of Light out of Glaſs into the Air there is a Reflexion as ſtrong as in its Paſſage out of Air into Glaſs, or rather a little ſtronger, and by many degrees ſtronger than in its Paſſage out of Glaſs into Water. And it ſeems not probable, that Air ſhould have more reflecting Parts than Water or Glaſs. But if that ſhould poſſibly be ſuppoſed, yet it will avail nothing, for the Reflexion is as ſtrong or ſtronger when all the Air is removed from the further Surface of the Glaſs, as when it is adjacent to it. *p.* 237. Now if any one ſhould imagine according to the Opinion of *Cartes*, that the ſubtle Matter at the further Surface of the Glaſs is denſer than any other Matter whatſoever, and upon that Account more ſtrong to reflect Light than any other Bodies; beſides that we have before demonſtrated that that Matter is only a fictitious Thing; and that if we ſhould allow this Matter, and its Power to reflect Light, the Light could not be propagated by it at the Beginning, but muſt immediately be all reflected back upon the lucid Body as ſoon as it is ſent forth from it; beſides theſe I ſay, he will be convinced of the Falſity of this Fiction by the following Experiment.

VII. If Light in its Paſſage out of Glaſs into Air be incident more obliquely than at an Angle of 40 or 41 Degrees, it is wholly reflected, if leſs obliquely, it is in great meaſure tranſmitted. Now it is not to be imagined, that Light, at one Degree of Obliquity, ſhould meet with Pores enough in the Air to tranſmit the greater Part of it; and at another degree of Obliquity ſhould meet with nothing but Parts to reflect it wholly; eſpecially, conſidering, that in its Paſſage out of Air into Glaſs, how oblique ſoever its Incidence be, it finds Pores enough in the Glaſs, to tranſmit a great Part of it. If any Man ſuppoſe, that it is not reflected by the Air, but by the outmoſt ſuperficial Parts of the Glaſs, that will appear to be falſe, by applying

led by it, and which receives its Action. And this is confirmed by Experience. For when the Light falls upon the Surface of any Opake and solid Body, as Gold or Steel, we see its Rays are reflected; and the Angle of this *Reflexion* is equal to the Angle of *Incidence*.

36. Now this being so in one solid Body, such as Gold or any other Metal; as it is a general Truth, it ought to extend to all Sorts of solid Bodies, and the Light ought to be reflected in Angles equal to those of their Incidence. Wherefore since the Pores of two transparent Bodies which touch each other, cannot exactly answer to one another; *36. That there are no transparent Bodies but reflect some Rays of Light.*

plying Water or Oil behind some part of the Glass instead of Air. For so in a convenient Obliquity of the Rays suppose of 45 or 46 Degrees, at which they are all reflected where the Air is adjacent to the Glass, they will be in great measure transmitted where the Water is adjacent to it; which argues, that their Reflexion or Transmission depends on the Constitution of the Air and Water or Oil behind the Glass, and not on the striking of the Rays upon the Parts of the Glass, *viz.* that the Rays are not reflected till they get to the further Surface of the Glass, and begin to go out of it: For if when they are going out of it, they fall upon Oil or Water, they go on, because the Attraction of the Glass is almost ballanced and rendred ineffectual, by the contrary Attraction of the Liquor that sticks to it. But if the Rays, which go out of the further Superficies, go into a *Vacuum*, which has no attractive Force, or into Air which has very little, and therefore cannot ballance the Attraction of the Glass, and render it ineffectual; then the attraction of the Glass reflects them, by drawing and bringing them back. And this is still more evident, by laying together two Prisms of Glass, or two Object-Glasses of very long Telescopes, the one plain, the other a little convex, and so compressing them, that they do not fully touch, nor are too far asunder: For the Light which falls upon the farther Surface of the first Glass, where the Interval between the Glasses, is not above the Ten hundred thousandth part of an Inch, will go through that Surface, and through the Air or *Vacuum* between the Glasses, and enter into the second Glass. But if the second Glass be taken away, the Light which goes out of the second Surface of the first Glass into the Air or *Vacuum* that is between the Glasses, will not go on forwards, but turns back into the first Glass, and is reflected. From whence it is evident, that the Rays are drawn back by the Power of the first Glass, there being nothing else to turn them back. *p.* 238, and 347. And hence it is also manifest, as was before observed, that the Rays are not reflected by any subtle Matter or Æther, because that Matter ought to reflect them not at all the less, when the second Glass is so placed as not quite to touch the first, than when it is quite taken away.

Lastly, If any one should ask; because we have ascribed the Reflexion of Rays to the Action of the whole Superficies of Bodies, without immediately touching them; how it comes to pass, that all Rays are not reflected by all Superficies; but while some are reflected, others are refracted and enter in: This excellent Person shows, that there are certain Vibrations (or some such kind of Property) both in the Bodies themselves, and in the Rays of Light, impressed upon the Rays, either by the Action of the Body which emits them, or by the Action of some other Bodies; whence it comes to pass, that those Rays, which are in that Part of their Vibration which conspires with the Motion of the Parts of the Body, enter into the Body, and are transmitted by Refraction; and those which are on the other Part of their Vibration, are reflected. *See Newt. Opt. p.* 255.

and therefore many of the Pores, of Air for inſtance, may meet with the ſolid Parts of Water, Glaſs, or Chryſtal; it is impoſſible, but that tranſparent Bodies muſt reflect ſome part of the Light which falls upon their Surface; and they muſt reflect ſo much the more, as the Rays fall more oblique, becauſe in that Poſition they meet with more of the ſolid Parts of the tranſparent Body upon which they fall.

37. How the Rays of Light are refracted as they paſs out of one tranſparent Medium *into another.*

37. Let us now conſider, what will happen to Rays that paſs out of one tranſparent Medium into another, upon whoſe Surface they fall obliquely. We foreſee 1 that they ought to be *refracted* agreeably to what was ſaid before concerning Refraction, becauſe theſe tranſparent Bodies being of a different Nature, the one may afford an eaſier Paſſage to the Light than the other, and ſo the Rays ought to be leſs inclined, or nearer to the Perpendicular on that Side which more eaſily admits them.

38. The harder a tranſparent Body is, ſo much the eaſier will the Light paſs through it.

38. Nor are we to think, that a tranſparent Body will afford ſo much the eaſier Paſſage to Light, by how much the eaſier it yields to other groſſer Bodies which make Way for themſelves, by removing its Parts: Just the contrary: For as the Paſſages for Light are already made,

1. *That they ought to be refracted*) The Rays are refracted, not by falling upon the very Superficies of Bodies, but without immediate contact, but that very ſame Power by which they are emitted or reflected, exerting it ſelf differently in different Circumſtances; as may be demonſtrated by the ſame Arguments as were before made uſe of about Reflection without Contact; and alſo by the following ones.

1. *Becauſe when Light goes out of Glaſs into Air, as obliquely as it can poſſibly do, if its Incidence be made ſtill more oblique, it becomes totally reflected. For the Power of the Glaſs, after it has refracted the Light as obliquely as is poſſible, if the Incidence be made ſtill more oblique, becomes too ſtrong to let any of its Rays go through, and by conſequence cauſes total Reflexions.*

2. *Becauſe Light is alternately reflected and tranſmitted by thin Plates of Glaſs for many Succeſſions accordingly as the Thickneſs of the Plate increaſes in an arithmetical Progreſſion. For here the Thickneſs of the Glaſs determines, whether that Power by which Glaſs acts upon Light ſhall cauſe it to be reflected, or ſuffer it to be tranſmitted.*

3. *Becauſe theſe Surfaces of tranſparent Bodies which have the greateſt refracting Power, reflect the greateſt quantity of Light.* Newt. Opt. p. 244.

4. Becauſe, although the Forces of Bodies to reflect and refract Light, are very nearly proportional to the Denſities of the ſame Bodies; yet unctuous and ſulphureous Bodies refract more than others of the ſame Denſity. For the Rays act with greater Force upon thoſe Bodies to ſet them on Fire, than they do upon others; and theſe Bodies act upon the Rays again with greater Force by mutual Attraction to refract them. *p.* 245, *&c.*

Laſtly. Becauſe, not only the Rays which are tranſmitted through Glaſs are reflected; but alſo thoſe which are near the Extremities of it in Air or in a *Vacuum*, or even thoſe which are near the extreme Parts of any opake Bodies (as the Edges of Knives, *&c.*) are bent by the Attraction of the Body. *p.* 293. *&c.*

it

it can move ſo much the eaſier as the Parts of the Body through which it paſſes, are more difficult to be put out of their Places; becauſe it is the leſs liable to loſe its Motion in paſſing; in the ſame manner as a Bowl will run eaſier upon the firm hard Ground, than upon ſoft Ground, or upon the Graſs. And thus as Water is in ſome Senſe harder than Air, and Glaſs harder than Water, and Chryſtal harder than Glaſs, it follows, [1] that Light ought to paſs more eaſily through Water, Glaſs and Chryſtal, than through Air; and its Rays ought to be leſs inclined, or to approach nearer to the Perpendicular in theſe Bodies than in Air.

39. This may be tried many Ways; I will ſhow you one that ſeems to me very evident. I cauſed a Braſs Box ABCD to be made, with a Cover to it of the ſame Metal. The Bottom BC was a Piece of *Venice* Chryſtal, under which I glued a piece of Paper, with ſeveral Marks made upon it at Pleaſure. I expoſed this Box to the Rays of the Sun, that a Ray, ſuch as FE might paſs through the Cover at the Hole E, and looking underneath, I obſerved the Point G, which the Ray came to; then without altering the Situation of the Box, which was full of Air only, I filled it with Water, which I poured in at the Hole M; then I obſerved, that the Ray did not come ſo far as G, but only to L, ſo that it was *nearer the Perpendicular* HI, than it was before.

39. An Experiment of the Refraction of Light in paſſing out of Air into Water. Tab. IV. Fig. 5.

40. Now to find whether a Ray paſſing out of Water into Air be turned *from the Perpendicular*, we may make uſe of a very common Experiment. We may put any Body, a piece of Money ſuppoſe, at the Bottom of a hollow Veſſel, which contains nothing but Air; then we may move our Eye B back, till the Edge of the Veſſel juſt hides the Object A; then let the Veſſel be filled with Water: After which, the Object without having changed its Place, will begin to appear by the Ray CB, which coming from A by C, will be bent, and removed *from the Perpendicular* ECF, whereas otherwiſe the Ray would have gone ſtreight on to D.

40. An Experiment of the Refraction of Light paſſing out of Water into Air. Tab. IV. Fig. 6.

1. *That Light ought to paſs more eaſily*) Mr. *Le Clerc* has committed a ſurprizing Miſtake here. *Therefore*, ſays he, *the greater the Reſiſtance of the Body is upon which the Ray falls, ſo much the more does it recede from the Perpendicular, and the leſs the Reſiſtance, the leſs does it recede. Wherefore a Ray falling upon Water out of Air, goes further from the Perpendicular; on the contrary, a Ray coming out of Water into Air approaches nearer to the Perpendicular; becauſe Air reſiſts it leſs than Water.* *Phyſ. Book* V. *Chap.* viii. *Sect.* 17, contrary to all Experience.

41. Of the Refraction of Light passing through a Glass Prism. Tab. IV. Fig. 7. 41. Because Refraction will be of great Use hereafter, it is worth while to explain the Nature of it fully, by considering how it is made, when Light passes out of Air into Glasses of various sorts of Figures. Suppose then, in the first Place [1] *a triangular Prism* ABC, upon one Side of which, suppose AB the Ray DE falls obliquely. From what was said before concerning the Rays passing out of Air into Glass, it follows, that it ought not to go on in a streight Line to F, but to G, in order to approach nearer the Line HEI, which is supposed to be drawn through the Point E upon which the Ray falls, and to be perpendicular to the Surface AB. After which, the Ray EG passing obliquely out of Glass into Air, ought not to go directly to L, but to M, because it is turned from the Perpendicular NGO.

42. Of the Refraction of Light passing through a Convex Glass. Tab. IV. Fig. 8. 42. Suppose now a Lens or a Glass convex on both Sides, such as is represented by the Figure 2B3K, and imagine a great many parrallel Rays, such as AB, CD, EF, to fall upon its Surface; now in order to find out how these Rays ought to be refracted, we must first draw through the Points B, D, F, Lines perpendicular to the Glass, that is, the Lines ABK, HDI, LFM, tending towards the Point G, which I suppose to be the Center of the Superficies 2B3. This being done, we may consider, that the Ray AB, being in the Perpendicular it self, ought not to be at all refracted as it passes out of Air into Glass, but to go on directly towards K, where it falls again perpendicular upon the Superficies of the Air 2K3 (because it comes from the Point R, which is the Center of this Superficies) and therefore it will continue to go strait on still towards G, without any Refraction. But as to the other Rays, such as CD, and EF, because they do not fall perpendicularly, it is evident, that they will not go directly to O and N, but will approach nearer to the Perpendiculars HI, LM, and go to Q and P, and by this means they will tend towards the Ray ABK; and because, having drawn the Lines TQI, SPM perpendicular through the Points P and Q, that is, the Lines which tend to the Point R, we find that the Rays DQ, FP fall obliquely on the Surface of the Air, we conclude, that they will be refracted, and go from the Perpendicular. So that DQ will not go directly to X but to G, and FP also will not go directly to V, but to

1. *A Triangular Prism*) See the Notes on Art. 65, below.

the

the fame Point G. The fame may be demonftrated of the Rays, that fall on the other Side of AB, which will be bent fo, as to interfect the firft [1] fomewhere near the Point G; thus we fee, that *it is the Property of a Convex-Glafs, to collect together the Rays of Light which fall parallel upon it.*

43. If whilft the Glafs remains in the fame Situation, parallel Rays fall upon it from fome other Place, we fhall find that they will meet together in fome other Point, and not in G; thus if they come from the right Side of thofe before drawn, they will meet on the left Side, *viz.* near Y; and on the contrary, if they come from the left Side, they will meet on the right Side fomewhere near Z. *43. Of the Refraction of the Rays which come from different Places.*

44. Let us confider in the Third Place, A Glafs that is thinner in the Middle than at the Edges, that is, a Glafs concave on both Sides, fuch as is reprefented by GBHIMK, and fuppofe the parallel Rays, AB, CD, EF, to fall upon it. Now in order to fee how they ought to be refracted, let us erect Perpendiculars at the Points B, D, F, where they enter the Glafs: This being done; fince the Ray AB coincides with the Perpendicular, it will enter the Glafs as far as M without any Refraction, where becaufe it falls perpendicularly upon the Superficies of the Air, it will no more be refracted at going out, than it was at entring into the Glafs, and confequently it will go directly to L. But becaufe the Ray CD falls obliquely upon the Surface of the Glafs, it will not go directly to P, but will turn to Q, becaufe it tends towards the Perpendicular NDO; and becaufe the Ray DQ falls obliquely upon the Surface of the Air alfo, it will not go directly to T, but will be refracted towards V, becaufe it goes from the Perpendicular RQS. So likewife if we examine the Ray EF, we fhall find by the like Way of Reafoning, that it will go to Y, and from thence to Z. Whence we fee, that *it is the Property of a Concave-Glafs* [2] *to difperfe the Rays which fall parallel upon it.* *44. Of the Refraction of Light paffing through a Concave-Glafs.* Tab. IV. Fig. 9.

1. *Somewhere near the Point G*) For the Rays are not collected together exactly into the fame Place, and the Focus is not in a Point, but in a fmall Line, that is, in part of the Line KG, fo that fome of the Rays meet with each other nearer the Point K than others of them. Thus for Inftance, if the Glafs be equally gibbous on both Sides, that Line will be $\frac{1}{3}$ of the whole Thicknefs BK. See *Hugen's Diopt.* Prop. 27. p. 94. and *Barrow, Sect.* V. Tab. IV. Fig. 8.

2. *To difperfe the Rays*) In fuch a manner that they may feem to come from a fmall Line, or fuch Part of the Line AB as the forementioned fmall Line was, into which they were gathered in paffing through a Convex-Glafs. Tab. IV. Fig. 9.

45. How the Light is refracted in passing thro' a Glass that has a great many Superficies. Tab. V. Fig. 1.

45. Let us consider in the Fourth Place, a Glass cut with several Surfaces on the one Side, but plain on the other, such as is represented by the Figure ABCDETS, and suppose the Rays FG, HI to fall parallel upon it: Draw Perpendiculars in the Points G and I; then because, from what was before said, these Rays ought to go towards the Perpendiculars, we are sure that they will bend towards K and Q; and because they again fall obliquely upon the Surface of the Air ST, we conclude that they will be refracted a second Time; so that GK will tend towards L, and IQ towards M; and because all the parallel Rays that fall upon the same plain Superficies, are equally inclined to it, they will be equally refracted, and consequently will be parallel when they come out, so that those which fall upon the Superficies BC will go along with the Ray KL, and those which fall upon AB, CD, DE, will go along with the Rays QM, PN, and RO.

46. Wherein the Lustre of precious Stones consists.

46. So that if the Surface TS were covered with an opake Body which receives all the Rays of Light that fall upon the Superficies AB, BC, CD, DE; it is evident that none of them will come upon the Parts SQ and RT, and consequently they will look darker; whereas the Part QR receiving all the Light which falls upon every one of the Surfaces ought to appear very bright; and herein consists the Lustre of a Diamond and other precious Stones which are any way transparent. For they will not shine, unless they be cut with a great many Superficies in such a Manner as to turn the Rays of Light towards one Place at the Bottom, where is a small Plate of Gold or Silver to receive the Light, and reflect it back to our Eyes.

47. Of the Refraction of Light passing thro' a plain Glass. Tab. V. Fig. 2.

47. Lastly, Let us suppose *a plain Glass of equal Thickness every where*, such as ABCD, upon which the parallel Rays, EF, GH, IL, if they fall obliquely, fall with equal Obliquity, so that they are equally refracted, by approaching every one of them towards the Perpendicular, and therefore go to M, O, and Q, being still parallel, and consequently equally inclined to the Surface BC; whence it follows, that in passing into Air, they recede equally from their Perpendiculars, and so continue always parallel. But we must observe here, that the Rays EF, GH, IL, which incline towards the Right, when they first enter into the Glass, are inclined as much towards the Left, when they come out of it: So that we may say, the Glass

I un-

[1] undoes that by the second Refraction, which it did by the first. [2]

48. Since Light not only shines, but heats also, we may here add; that though we cannot perceive any Inequality in the Action of luminous Bodies, but that they seem to impell uniformly the second Element which surrounds them, towards those Bodies which terminate their Action; yet Reason shows us, that they act more strongly at sometimes than at others; not only because their Parts are not all equal, nor are they always the same which are applied to the same surrounding Matter to impell it; but also because this Action is at first communicated to a transparent and liquid Medium, the Parts of which continually move out of their Places. And this causes the small Globules of the second Element to impress a kind of Trembling upon the Parts of the Bodies to which they are impelled by the luminous Bodies; and because Heat consists in such a kind of Agitation, it follows, that all luminous Bodies ought to produce some Heat.

48. That all Sorts of Light are capable of producing Heat.

49. However, it may happen that this Heat may not be at all perceivable, either because of the Weakness of the luminous Body, or because the *Organ* upon which it acts is hotter than it. Thus if coming from a Fire we expose our selves in a cold Night to the Rays of the Moon, we shall find it very cold; because in such Circumstances, we give more Heat to the Air which surrounds us, than that that does to us.

49. Why we do not feel the Heat of some luminous Bodies.

50. And as the Sun is very bright, so it ought to raise the most sensible Heat in us; and so we find by Experience every Day that it does; nay to that Degree, that when its Rays are collected by a concave-Glass, they will not only set combustible Bodies on which they fall, on Fire, but will melt Metals, Stones, and Flints,

50. The surprising Power of the Sun's Heat.

1. *Undoes that by the second Refraction*) We must have a Care of thinking, that the second Refraction so undoes the first, that the Object is seen in its true Place; for the Ray BQ extended backwards will not coincide with the Ray LI, but fall to the right Hand of it, and that so much the more, the thicker the Glass is. But as to Colours the second Refraction does indeed undo the first. *See the Notes on Art. 65.*

Tab. V. Fig. 2.

2. That double and irregular Refraction of *Island Chrystal*, whereby not only the oblique Rays are separated into two Parts on the same Superficies by a double Refraction; but also those that fall perpendicularly are half of them refacted likewise, is very different from all those hitherto explained: The Explication of this you may see in *Newt. Opt.* p. 331.

which

which are very difficult to melt with Fire; as I my ſelf have ſeen.

58. *That the coloured Body is not the immediate Cauſe of the Senſation of Colour.* 51. Having ſufficiently explained the Nature of Light, and the common Properties of it; the firſt Thing that we obſerve concerning Colours, is, that they are not perceived by the immediate Application of the coloured Object to the *Organ* of Senſation: From whence it follows, that it does not of it ſelf excite in us that Senſation of Colour which we have upon looking on it; for we certainly know, that one Body cannot act upon another without immediate Contact; but whatever there may be in the coloured Object, in which its Colour conſiſts, we muſt think, that it acts thereby upon ſome Medium which it finds, and by that Means acts afterwards upon our *Organ* of Senſation.

52. *That it is the different Modification of the Rays of Light that cauſes the different Senſation of Colours in us.* 52. If the coloured Object only had been conſidered, which generally is at reſt, when it affects the Senſes, I doubt the manner of its acting upon the *Medium* would never have been diſcovered, and conſequently we ſhould never have known diſtinctly what Colour conſiſts in. But if we obſerve, that ſuch Bodies are not to be perceived in the Dark; and that in order for them to appear coloured, it is neceſſary for them to have ſome Light, the Nature of which is to be reflected, when it meets with a Body which it cannot penetrate; it is eaſy to conclude, that it is the Light which acts upon our *Organ* of Senſation to make us perceive any Colour, and that the whole Action of the *coloured Body* conſiſts in giving it [1] *ſome Modification which it had not before.*

53. This

1. *Some Modification which it had not before*) In order to explain the Nature of Colours, we muſt obſerve,

(1.) That it is found by Experience, that the Rays of Light are compounded of Particles different from one another: that is, which are (as is highly probable) ſome larger and ſome ſmaller.

(2.) That a Ray, ſuch as FE, falling upon a refracting Superficies in a dark Room, is not refracted whole to L, but as it were ſplit into a great many ſmaller Rays, ſome of which are refracted to L, others of them to ſome other Points betwixt L and G: That is, (as is very probable likewiſe) thoſe Particles of Light which are ſmalleſt, are the eaſieſt of all, and the moſt turned out of a ſtraight Line towards L, by the Action of the refracting Superficies; and the reſt of them, according as they exceed each other in Bigneſs, are more difficultly, and leſs turned out of a right Line, to the Points betwixt G and L.

Tab. IV. Fig. 5.

(3.) Thoſe Particles of Light which are moſt refracted, make a ſmall Ray of a Violet Colour; that is, (as is very likely) the ſmalleſt Particles of Light, ſeparated from the reſt in this manner, excite the ſhorteſt Vibrations in the *Tunica Retina*, to be propagated from thence along the ſolid Fibres of the optick Nerves into the Brain, there to excite the Senſation of Violet Colour, the darkeſt and the fainteſt of all Colours. And thoſe Particles which are

53. This being supposed, there cannot be an easier Way to come at the certain Knowledge of the Nature of Colours. For since Light is nothing else but a particular Motion of the small Globules of the second Element, or at least a Disposition to a particular Sort of Motion; nothing more is requisite for the understanding of Colours, but only to examine the different Modifications which this Motion is capable of, and to find out what there is in the Bodies which we call coloured, to cause these Modifications. Now the first Thing which offers it self, and which is the most simple Modification, is this, *viz.* That this Motion cannot but be weak, if all the Rays

53. That the Roughness of the Superficies of a Body does alone modify the Action of Light.

are refracted least, they make a small Ray of a red Colour; that is, the biggest Particles of Light, excite the longest Vibrations in the *Tunica Retina*, in order to raise the Sensation of a red Colour, the brightest of all Colours; and the other Particles are also every one separated into small Rays, according to their Bigness and Refrangibility, in order to excite intermediate Vibrations, which raise the Sensations of intermediate Colours. Much in the same manner, as the Vibrations of Air, according to their different Bignesses, cause Sensations of different Sounds.

(4.) The Colours therefore of those small Rays, since they are not accidental Modifications of them, but connate, original, and necessary Properties of them, consisting (as is highly probable) in the different Magnitudes of them, are permament and unchangeable; that is, such as cannot be altered by any future Refraction, Reflexion, or any other Modification.

(5.) As the Rays of different Colours begin in this manner to be separated by the *single* Refraction of *one* Superficies; so that Separation is much more compleated (so as very easily to be perceived by our Senses) by that *double* Refraction (the First being increased by the Second) which is made in the two *Sides* of a Triangular-Glass Prism, (the Phænomena of which are fully explained in the *Notes on Art,* 65. below) and in the double Refraction made in the Superficies of Glasses of other Figures, according as their Superficies are further from being parallel to each other, such as the Object Glasses of Telescopes, *&c.* (and this is the Reason why they cannot be made perfect, *viz.* because of the Separation of the coloured Rays. *See the Notes on Chap.* xxxiii. *Art,* 28.)

(6.) As the Rays of different Colours are separated by the Refractions of Prisms, and other thick Bodies, so are they likewise separated in another manner, in very thin Plates of any transparent Matter. For all Plates, which are thinner than a certain determinate Thickness, transmit the Rays of all Colours, and reflect none; but as their Thickness increases in an Arithmetical Progression, they begin to reflect, first, Rays that are *intirely* Blue; then Green, Yellow, Red, in order; and again, Blue, Green, Yellow, Red; *but more and more faint and mixed*; till at last, when they come to a certain Thickness, they reflect the Rays of all Colours throughly mixed together, just as they fell upon them, and these make White. And in that Part of the thin Plate where it reflects any Colour, for Instance, Blue, it always transmits the contrary Colour, *viz.* Red, or Yellow: For the truth of all which Phænomena, found out by numberless Experiments, and for the Calculation of what Thickness the Plate ought to be, to reflect particular Colours, and for the Reasons why Plates of particular Thickness reflect particular Colours in this Manner: See the eminent Sir *Isaac Newton* most clearly discoursing in his *Opt. Book* II.

(7.) All natural Bodies are made up of very thin transparent small Plates; which, if they be so regularly disposed, with regard to each other, that there is no Reflexions or

Rays of Light which fall upon an Object in a certain Order, and in a certain Quantity, be not reflected back in the same Order, nor in the same Quantity towards one determinate Place of the Medium where the Eye is fixed: And we are sure, that this must necessarily happen, if the very small Particles of the illuminated Body are so disposed, as to make a rough and uneven Superficies; for then the Rays which come as it were parallel from the luminous Body, fall upon such a Superficies with all sorts of Obliquities, and therefore are scattered and reflected all Ways; and this is the Reason why the Eye does not receive the Light with its full Force; but only a certain small Number of Rays are determined by this Superficies to come to the Place where the Eye is fixed; and hence we may conclude, that there is some particular Colour which consists only *in the Roughness of the Surface of the coloured Body, and which gives no other Modification to the Light, but only this, that it reflects it all ways indifferently in the same manner as it received it.*

54. What the Nature of Whiteness consists in. 54. Now as this is the least Modification of Light that can be; so the Body which causes it ought to resemble the luminous Body as much as possible, that is, it ought to excite in us the Sensation of *Whiteness*, which comes the nearest to Light of any Colour. And this is confirmed by Experience; for the white Colour of *Estamps* Sand is found to consist in this, that every Grain does thus reflect any Ray of Light all Ways. For when we look upon any of the Grains with a *Microscope*, they have no Colour at all, but are transparent, like small Pieces of Chrystal of all Shapes, or like little Diamonds which af-

or Refractions in their Interstices, then they constitute a *transparent* Body. But if their Interstices be so large, and filled with such Matter, or so empty (proportionably to the Density of the Parts themselves) that there are several Reflexions and Refractions made within the Body, then that Body is *Opake*. (*See Art.* 5 *above*) Further, those opake Bodies which are made up of the thinnest small Plates of all, are *Black*; and those that are made up of the thickest small Plates or of such as are of very different Thicknesses, and are therefore fitted to reflect all Colours, such as the Froth of Water, these are *White*; and those which are made up of small Plates, the most of which are of some intermediate Thickness, are therefore *Blue, Green, Yellow, or Red*, viz. by reflecting not all the Rays of that Colour, but more of those than of any other Colours; the greatest Part of which other, they either suffocate, and by intercepting them, extinguish them quite, or else they transmit them; whence it is, that some Liquors (for Instance, an Infusion of Lignum Nephriticum) appears Red or Yellow by a reflected Light; and Blue by a transmitted Light; and Leaf-Gold appears Yellow when looked upon, but Green or Blue when looked through.

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ford ſuch a Paſſage to the Light, that they reflect it all Ways in the ſame manner as they received it.

55. That Roughneſs is ſufficient to cauſe Whiteneſs.

55. We may further conjecture, nay, we may be aſſured, that *the Eſſence of Whiteneſs conſiſts in nothing elſe but the Roughneſs of the white Body*, if we conſider, that we cannot make ſome Bodies *rough*, but they will alſo become *white* at the ſame Time, nor take away their *Roughneſs*, but we muſt likewiſe take away their *Whiteneſs*. Thus Goldſmiths make Silver *white*, by putting it firſt into the Fire, to take off all the Droſs and Dirt which ſoils it; and then dipping it in boyling Water, into which they caſt a certain Quantity of *Tartar* and *common Salt* (which are corroſive Bodies, and proper to make the Superficies of Silver rough and uneven.) And to take off the *Whiteneſs*, they do nothing more but rub the Silver with what they call a Blood-ſtone, which is very hard and ſmooth; which by preſſing upon the Part it is applied to, muſt neceſſarily depreſs the Parts which ſtick up, and raiſe the Parts which ſink in, that is, take off the Roughneſs.

56. Why a white Body looks ſo, when viewed every Way.

56. As we take it for granted, that a white Body does not abſorb any of the Rays, but that its Superficies reflects them all Ways indifferently, it follows, that we cannot place the Eye any where, but that it will receive pretty near the ſame Number of Rays as if it were placed any where elſe; and conſequently the Body ought to appear white from what Side ſoever it is viewed. But the Caſe of plain poliſhed Bodies, ſuch as Looking-Glaſſes, is different; for when they receive the parallel Rays of Light from one Side only, they can reflect them to the other Side only, where they may dazzle the Eye, but they will not reflect Rays to any other Part.

57. Of the Nature of Blackneſs.

57. As *Black* is contrary to *White*, there is no doubt but that the Eſſence of *Blackneſs* conſiſts in the contrary to that of *Whiteneſs*. Wherefore, as it is neceſſary, in order for a Body to look *White*, that it ſhould reflect the Light which falls upon it towards all Parts in the ſame manner as it receives it, ſo that there can be no Place, but that a ſufficient Quantity of Rays muſt affect our Eye: So likewiſe ought we to think, that in order to perceive *Blackneſs*, there muſt come no Rays at all to the Eye; and conſequently the Bodies which we call *Black*, and which appear ſo to our Senſes, abſorb all the Rays in ſuch a manner, that they reflect none of them to make any Impreſſion upon the Eye: And becauſe a Body cannot deſtroy the Motion of another Body, but by gaining it

it itself, it is easy to conceive, that *the Parts of Black Bodies are very fine and broken, so as to be easily shaken.*

58. Why a great many Bodies that are not Black, do yet appear so. 58. And this is confirmed from hence. First, That *Darkness*, that is, those Places where Bodies having no Light falling upon them, can reflect no Rays to the Eyes, [1] appears *Black*. Secondly, *Shadows*, or those Places, which, by reason of the Interposition of some opake Body, do not receive the Rays of Light from the luminous Body, or receive but a few of them, appear *Black*. Lastly, *A well-polished Body*, which does receive a great many Rays of Light, but reflects them to the Side opposite to us, appears *Black*.

59. Why Wood when it is burnt to a Coal, turns Black. 59. These Things being allowed, it will not seem strange, that Flame which is so bright, should convert White Wood into a *Black* Coal. For it is manifest, that the Wood has lost a great many of its Particles, which served to nourish the Flame; wherefore the greatest Part of the remaining ones are so [2] disunited, and easily shaken, that they absorb almost all the Light that falls upon them.

60. That all the Parts of a Coal are not Black. 60. I say, the greatest Part only are disunited, and easy to be put in Motion, and not all of them; for it may happen, that the finest Particles which are on the Outside of the Coal, may be like Down to cover the more solid Parts, and such as are capable of reflecting a sufficient Quantity of Rays of Light: And thus we see, that after the Fire has carried off all that it can consume of the Coal; there yet remains a great many Parts which compose the Cinder, which are pretty solid, for they appear of a whitish Colour.

61. That, cæteris paribus, Black Bodies ought to weigh less than White. 61. Because the Particles of Black Bodies are more disunited than those of White Bodies, it follows, that they contain less of their own proper Matter in the same Bulk than these other. And because the more a Body has of heavy Matter, the heavier ought it to weigh, therefore

1. *Appears Black*) This is taken out of *Aristotle's first Book of Colours. Chap.* 1. *There are Three Ways that Black appears to us. Where we cannot see at all, it is naturally Black. Or where there is no Light brought to our Eyes. Or where the reflected Light is very rare and small; and thus Shadows appear Black.*

2. *Disunited and easily shaken*) And they very easily and strongly make other Bodies, to which they are applied, of a Black Colour, because the very small Particles of the Coal, the Number of which is very great, easily cover over the grosser Particles of other Bodies. But this Opinion, *concerning the Nature of Blackness*, in general is very much confirmed from hence, *viz.* that Black Bodies are sooner heated; and if wetted, grow sooner dry than White, as is confirmed by very certain Experiments. *See Art.* 62.

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we ought to conclude, that *cæteris paribus* of two equal Bodies, the one *Black*, and the other *White*, the *latter* ought to weigh more than the *other*; Wherefore the *Wood* ought to weigh more than the *Coal*; and a piece of *White* Marble more than a Piece of *Black*, of the fame Bignefs.

62. Having thus explained the Nature of *White* and *Black*, we fhall eafily underftand the Reafon why the Rays of the Sun collected by a Convex-Glafs, will not *burn* at all, or *burn* with greater Difficulty *White* Bodies; but will eafily *kindle Black Bodies*, though they be both combuftible. For it is evident, that the *White* Body which reflects all the Rays that fall upon it, is not fhaked by them, and that the *Black* Body which abforbs and choaks all the Rays, therefore abforbs them becaufe it receives all their Motion; by which Means it begins to grow hot, and at laft takes Fire.

62. Why the Rays of the Sun, collected by a Convex-Glafs, burn Black Bodies eafier than they do White.

63. Hence we fee the Reafon of a Fact which we fhould not know but by Experience; which is, that *White* Bodies weary the Sight, and *Black* ones refrefh it. For we cannot look upon *White*, but we muft receive the Impreffion of a great Quantity of Rays, which fatigues the Sight, whereas we fee *Black* when no Rays come to us, which refrefhes it.

63. Why White Bodies weary the Sight, and Black Ones refrefh it.

64. From all which it follows, that thofe Bodies are the *whiteft* which reflect all Ways, and with the fame Force, all the Light which falls upon them; and on the contrary, that thofe Bodies are the *blackeft*, which abforb the Light the moft that can be. Such we have reafon to believe *black Velvet* to be, becaufe the fmall Threads of Silk of which it is made, are like Briftles, and fo placed as to be as rough as poffible; wherefore it is the blackeft Thing in the World.

64. What are the whiteft and blackeft Bodies of all.

65. As to the Modifications of the Rays of Light, which excite in us the Senfation of other Colours; as *Red*, *Yellow*, and *Blue*, we ought to think that they confift in this, *viz.* that the fmall Globules of the fecond Element, which compofe the Rays that are reflected from all fuch Bodies, have not fo much Force or fo great a Difpofition to go on in a ftreight Line, as the Globules of the Rays which are reflected from white Bodies, and therefore inftead thereof, they are fome way turned about their own Centers; and fo part of the Force which they had before to go on in a ftreight Line, is fpent upon this Motion Which may be juftified from hence, that we cannot conceive what other Alteration than this can hap-

65. Of the Nature of other Colours.

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pen to the Rays of Light, in passing through 1 a triangular Glass *Prism*; and yet we see, that by going through this *Prism*, they are capable of exciting in us the Sensation of *Red*, *Yellow*, and *Blue*.

66. But

1. *A triangular Glass Prism*) Because the Experiments of a triangular Prism, are as it were the Touchstone by which every Hypothesis, and every Theory, concerning the Nature and Properties of Colours, is to be examined and tried; I shall not think it too much trouble briefly to enumerate here the principal Phænomena as they are explained by the famous Sir *Isaac Newton* all along in his Opticks. 1. Then, the Rays of Light transmitted through a Prism, paint an Image upon the opposite Wall, distinguished into various Colours, the Chief of which are, Red, Yellow, Green, Blue, and Violet. 2. This Image is not round, but when the Angle of the Prism is about 60 or 65 Degrees, five times as long as it is broad. 3. Those Rays which make a Yellow Colour, deviate more from a streight Line, than those which make a Red; and those which make a green Colour, deviate more than those that make a Yellow, *&c.* and those which make a violet Colour deviate most of all. 4. If the Prism, through which the Rays are transmitted, be so turned about its Axis, that the Red, Yellow, Green, *&c.* Rays fall in order through a small Hole upon another Prism, about twelve Foot distance, and be turned another Way; the Yellow, *&c* Rays, though they fall with the same Incidence upon the second Prism as the Red do, yet they will not be turned upon the same Place as the Red, but will be carried further towards that Part, to which the Refraction is made. Further, if in the Place of the second Prism they be received by a Glass that is a little gibbous, the Yellow, Green, *&c.* Rays, every one in their Order, will meet in a Focus sooner than the Red. 5. The Colours of the coloured Rays, well separated, (the manner of doing which, you may see in *Newt. Opt.* p. 54, *&c.*) cannot be destroyed, nor any Way altered by repeated Refractions. 6. The Colours of coloured Rays cannot be at all altered, by passing through a Place that is Light, nor by crossing each other; nor by the Confines of a Shadow; nor by reflecting them from any natural Bodies in a Place dark every where else. 7. All the coloured Rays together, collected either by several Prisms, or by a Convex or Concave-Glass, make White, but when separated, after crossing each other, they all exhibit their own Colour. 8. If the Rays of the Sun, fall upon the inward Superficies of the Prism, with the greatest Obliquity that any of the Rays can be transmitted at, those that are reflected will be Violet, and those which are transmitted will be Red. 9. If there be two Prisms, the one filled with a Red Liquor, and the other with a Blue; the two Prisms clapped together will be opake, though if they be both filled with a red or blue Liquor, they will be transparent when clapped together. 10. All natural Bodies, but especially White, when looked at through a Prism, appear to be bordered on one Side with a red and yellow Colour, and on the other Side with a Violet and Blue. 11. If two Prisms be so placed, that the Red of the one, and the Purple of the other, be mixed on a proper Piece of Paper, surrounded with Darkness, there will be a pale Image; which if it be looked upon through a third Prism at a due Distance, will appear double, Red and purple. 12. So likewise, if two Sorts of Powder, the one perfectly Red, and the other perfectly Blue, be mixed together, and any small Body be dawbed thick with that Mixture, it will appear to the Eye through a Prism, to have two Images, a red and a blue One.

These are the most general Phænomena of the Prism; (to reckon up all the Particulars which are worth observing, would be endless) from which it appears at first Sight, that the Colours cannot consist in the turning round of the Globules only, according to *Cartes*, nor in the Obliquity

66. But for the clearer underftanding hereof; let the Side BC of the Prifm ABC be covered all over with fome opake Body, except the Place DE, where there is to be a Hole in the opake Body for fome of the Rays FI, GL, coming from the Sun FG to pafs through; which, *66. Of the Action of the Rays of Light paffing through a Glafs Prifm.* Tab. V. Fig. 3.

liquity of the Pulfes of the ætherial Matter, as Mr. *Hook* thought, *Microg. Obfer.* 9, nor in the Light being thick and rare or flower moved; as the famous *Barrow* conjectures, *Lect.* 12. towards the End. But thefe and all other Phænomena of Colours, are very eafily and clearly explained, by the true Theory of that incomparable Perfon fo often cited.

For Firft. *The Rays of Light tranfmitted through a Prifm, paint an Image upon the oppofite Wall, diftinguifhed into various Colours*: Becaufe the coloured Rays are feparated by Refraction. Thus the blue Rays, for Inftance, marked with the prick'd Line, which begin to be feparated in the Side *ca* of the Prifm *abc* (and alfo in the firft Superficies of the Globe of Water *abc*) from the reft by the firft Refraction in *dd*; are feparated ftill more in *bc* the other Side of the Prifm (and alfo in coming out of the Globe *abc*) by a fecond Refraction towards the fame part in *ee*: But, on the contrary, in the plane Glafs *abcf* (and alfo in the Prifm *glo* placed in another Situation, the blue Rays, which begin to be feparated from the reft in the firft Superficies in *dd*, go out parallel in the other Superficies, the Refraction being made the contrary Way, that is, they are mixed again with the Colours of the other Rays. Tab. XXII. Fig. 1. Fig. 2. Fig. 4. Fig. 3.

Secondly. *This Image is not round, but about five times as long as it is broad*: Becaufe fome Rays are more refracted than others, and therefore they reprefent a great many Images of the Sun like one Image drawn into a great Length.

Thirdly and Fourthly. *Thofe Rays which make a yellow Colour, deviate more from a ftreight Line, than thofe which make a Red, and thofe which make a green Colour, deviate more than thofe that make a Yellow,* &c. *and thofe which make a violet Colour, deviate moft of all*: *And further, if the Prifm through which the Rays are tranfmitted, be fo turned about its Axis, that the Red, Yellow, Green,* &c. *Rays, fall in order thro' a fmall Hole upon another Prifm about twelve Foot diftance, and be turned another Way; the Yellow,* &c. *Rays, though they fall with the fame Incidence upon the fecond Prifm as the Red do, yet they will not be turned upon the fame Place as the Red, but will be carried further towards that Part, to which the Refraction is made. Further, if in the Place of the fecond Prifm, they be received by a Glafs that is a little gibbous, the Yellow, Green,* &c. *Rays, every one in their order, will meet in a Focus fooner than the Red*: Becaufe the Yellow Rays are more refracted than the Red, and the Green than the Yellow, and the Blue and Violet moft of all.

Fifthly and Sixthly. *The Colour of the coloured Rays well feparated, cannot be deftroyed, nor any Way altered, by repeated Refractions, nor by paffing through a light Place, nor by croffing each other, nor by the Confines of a Shadow, nor by reflecting them from any natural Bodies in a Place dark every where elfe*: Becaufe their Colours are not Modifications arifing from Refraction, but immutable Properties belonging to their Nature.

Seventhly. *All the coloured Rays together, collected either by feveral Prifms, or by a convex or concave Glafs, make White; but when feparated after croffing each other, they all exhibit their own Colour*: For as the Ray, before it was divided into feveral Parts by Refraction, was White; fo by thofe Parts being mixed together again, it becomes White again; and the coloured Rays, when they unite, do not deftroy one another, but are only mixed together. And hence it is, that Red, Yellow, Green, Blue, and Violet Powders mixed together in a certain Proportion, are fomewhat Whitifh; that is, are of fuch a Colour as arifes from a Mixture of White and

Q Black,

which, according to what was said before, will be refracted in such a manner, that the Ray FI will tend towards M, and from thence to N, and GL will go to O, and from thence to P. Whence it is to be observed, that FI, GL are therefore turned out of the Way in this manner, because the small Globules at their entring into the Glass, find an easier Passage this Way, that is towards the right Hand, than towards the Left. Thus for instance; Let STV be one of these Globules, we must

Black, and would be entirely White, if some of the Rays were not absorbed: So likewise if a round piece of Paper be painted with all those Colours distinct from each other, and in a certain Proportion, and then turned very quick round upon its Center, that by the Swiftness of the Motion, all the Species of Colours may be mixed together in the Eye; the particular Colours will immediately vanish, and the Paper will look all of one Colour, which is a Medium betwixt White and Black.

Eighthly. *If the Rays of the Sun fall upon the inward Superficies of the Prism, with the greatest Obliquity that any of the Rays can be transmitted at, those which are reflected will be Violet, and those which are transmitted, will be Red*: Because the Rays, being coloured before they were refracted at all, and the more they are capable of being refracted, the sooner are they reflected also; are separated in this manner.

Ninthly. *If there be two Prisms, the one filled with a Red Liquor, and the other with a Blue, the two Prisms, clapped together, will be opake, tho' if they be both filled with a Red or a Blue Liquor, they will be transparent when clapped together*: Because one of them transmit none but Red Rays, and the other none but Blue, therefore when put together, they can transmit none at all.

Tenthly. *All natural Bodies, but especially white ones, when looked at through a Prism, appear to be bordered on one Side, with a Red and Yellow Colour, and on the other Side with a Blue and Violet*. Because those Borders are the Extremities of whole Images, which the Rays of every Species, according as they are more or less refracted, exhibit at a greater or less distance from the true Place of the Object.

Eleventhly and Twelfthly. *If two Prisms be so placed, that the Red of the one, and the Purple of the other, be mixed on a Piece of Paper fitted for the purpose and surrounded with Darkness; there will be a pale Image, which if it be looked upon through a third Prism, at a due distance, will appear double, Red and Purple*: So likewise, *if two Sorts of Powder, the one perfectly Red, and the other perfectly Blue, be mixed together, and any small Body be dawbed thick with that Mixture, it will appear to the Eye, through a Prism, to have two Images, a Red and a Blue one*: Because the Red Rays, and the Purple or Blue ones are separated by an unequal Refraction.

Moreover, thirteenthly. *If the Rays which are transmitted through a gibbous Glass, be received upon a Piece of Paper before they meet in the* Focus, *the Confines of Light and Shadow will seem tinged with a red Colour, but if beyond the* Focus *with a Blue*: Because in the former Case, the Red Rays, which are somewhat less refracted, are uppermost; but after crossing in the *Focus*, the Blue are so.

Fourteenthly. *If the Rays that go through one half of the Pupil be intercepted by any opake Body put close to the Eye, the Extremities of the Objects beyond, will appear tinged with Colours, as they do through a Prism, but not so vivid*: Because the Rays which are transmitted through the other part of the Pupil, are separated into Colours by Refraction, and will not be diluted by the Mixture of the intercepted Rays, which would have been refracted the contrary way: And hence it is, that a Body which looked at through two Holes in a Piece of Paper, appears double, appears tinged with Colours also.

think

think that the Superficies AB determines it to move towards S, rather than towards V, and consequently to turn about its Center in the order of the Letters STV, which it will continue to do the whole Length of the Line IM. And becaufe when it is come to M, where it undergoes a Refraction towards the right Hand; this is a Reafon why it fhould be turned about again in like manner; therefore it muft be acknowledged, that the fmall Globules which come out of the Glafs towards N, are fo modified, that befides the Difpofition they have to move ftreight along, they have a Difpofition alfo to turn about their own Centers.

67. What was affirmed of the Globules of the Ray FIMN is to be underftood alfo of thofe of the Ray GLOP and of all the other intermediate Rays. But after the fecond Refraction, which is made at the Surface BC, we find on the one Hand, that the fmall Globules of the Ray MN are turned about in the fame manner as they were at firft, from a new Caufe; for the Shadow on the Side D flackens the Motion of the Globule M on the fame Side; and the Rays which are between IMN and LOP being ftronger than the other, prefs upon the Side Q of the fame Globule, and becaufe they move the fame Way as it turns, they quicken its Motion on this Side: And on the other Hand, we are affured, that the Globules of the Ray GLOP, have the Rotation which they had acquired from thefe two Refractions hindred by Two Things. Firft, From the Shadow which hinders them on that Side on which they were moft ftrongly impelled, and retards their Motion. And, Secondly, Becaufe they are impelled on the other Side, by Rays that are ftronger, and which imprefs a Motion upon them, contrary to that of their Rotation.

67. That the Shadow caufes divers Modifications in thefe Rays. Tab. V. Fig. 3.

68. Having thus confidered the feveral Alterations, and the Reafons of thofe Alterations which may happen to the Rays of Light in their Way to the opake Body NP; we find, that the Globules which fall near N *are turned round with a greater Force, than that with which they are moved on in a ftreight Line*; and on the contrary, that the Globules of the Rays which fall near P, *move on in a ftraight Line, with a greater Force than that with which they turn round their Centers.* And Laftly, That there intermediate Rays, about X, *have pretty near the fame Force to turn round, as to move ftreight along.* But by Experience we find, that we fee *Red* in N, *Blue* in P, *Yellow* in X, *Orange* between N and X, and *Green* between X and P;

68. What the Modifications of thofe Rays are which caufe Red and Yellow, and Blue. Tab. V. Fig. 3.

 whence

whence it appears what the particular Dispositions of the Globules which compose the Rays of Light are, to excite in us these Sensations.

69. *What the Colours of coloured Bodies consist in.* 69. Now there are two Things in the Objects [1] which we call coloured, which may cause the same Modifications in the Light, as those acquired in passing through a *Prism*. For, First, Their Particles may be so transparent, that the Rays of Light may penetrate a little Way into them, and be refracted, before they are reflected: Secondly, (and which may produce the same Effect, and be the Cause of the Colours of different Objects) Their Particles may be so small and uneven, that the Globules of the Rays of Light which fall upon them, may communicate some of their Motion to them, and by that Means they may be turned round and reflected back, in the same manner as a Ball thrown with great Force upon the Grass, is stopped a little by the Spires and turned round.

70. *That coloured Bodies are in some measure transparent.* 70. Neither can it be doubted, but that some of the Particles of coloured Bodies are really transparent, as may be seen by the Help of a *Microscope*, in all kinds of Sand, Flint-stone, Marble, Sugar, Silk, Wool, Hair, Herbs, and an infinite number of other Bodies.

71. *That the Surfaces of coloured Bodies is made rough by colouring them.* 71. And that the Particles are very small and broken, is evident, not only from hence, that coloured Bodies appear coloured when viewed all Ways, but is further confirmed from the manner in which Colours are made by the *Dyers*. For, since Brasil-Wood, Indian-Wood, Indico, Yellow-Weed, *&c.* will not tincture any Thing with a red, violet, blue, yellow *&c.* Colour, unless there be some Allum mixed with them, we must conclude, that this penetrating corrosive Body insinuates itself into the Pores of the Cloth, and dilates them; whereby there is Room made for the Water to enter tinctured with the several Colours, which sink into the Cloth in such a manner, as to leave some on the Superficies, which causes a kind of Roughness, and makes it capable of all the different Modifications of Light.

72. *That the Particles of black Bodies are more broken than those of any other coloured Bodies.* 72. After what has been said concerning *Dying*, it is necessary to make one particular Observation about Black; and that is, that because the Roughness, in which this Colour consists, must be the greatest that can be, to extinguish all the Rays; therefore in dying Cloth of a Black Colour, Allum and Nut-galls are not sufficient alone;

1. *Which we call coloured*) See above *Art.* 52.

but

but there must be Vitriol instead of Allum, which is more corrosive than Allum; and further, to make the Vitriol corrode the more, they put the Cloths to be died into the Copper, and leave them for some time in the boiling Liquor; whereas in dying of other Colours, they only dip the Cloth several times into the Liquor, which is but just warm.

73. Since the Particles of *black* Bodies are the most uneven, it is easy to imagine, that Cloths and other Stuffs of this Colour must *tear* and *wear* sooner than those of any other Colour.

73. Why black Cloth wears sooner than other.

74. Further, if we consider, that the darkest Colours require that the Particles should be the smallest that can be; it is evident, that we may easily make a light Piece of Cloth of a dark Colour, because it requires only to have its Superficies made rough; but because it is very difficult to make it smooth again; therefore Cloth of a dark Colour, can very hardly be died of a lighter.

74. Why Cloths of light Colours will dye of darker Colours, but not the contrary.

75. Now, when I speak of the Particles of coloured Bodies, I mean only the very smallest of all; many Hundreds of which may be united together differently, in order to compose grosser Parts which may be of very different Figures, in the same manner as different Buildings may be formed of Bricks, which are all alike. Thus we know, that coloured Bodies act upon the *Eyes* by their *smallest* Particles, and upon the *Tongue* by those which are *larger*, and composed of the other; whence we conclude, that Things of the same *Colour* have not necessarily the same *Taste*.

75. It is not necessary that Things of the same Colour should have the same Taste.

76. Since there are two Sorts of Particles in the same Body, this shows us, that if we make any Alteration in the smaller Sort, the Colour must be changed likewise. And so we experience it in Herbs bruised in a Mortar; and in Colours which Painters grind upon a Stone, such as Vermillion and Orpiment. But if the Body be such, that the smallest Particles of it cannot be altered, neither can the Colour be changed; as we see in some Paints, which are not so easy to be altered as those mentioned; especially as Herbs, whose Particles have before a proper Motion of their own, as being in some measure liquid, which helps to dash them against each other, and to separate them into smaller Particles than they would otherwise be.

76. By altering the smallest Particles of any Body the Colour is altered also.

77. *How a white Body ought to appear, which receives Rays already modified.* 77. From what has been said concerning coloured Bodies, and particularly concerning a white Body; we may infer, that if there fall no other Rays of Light upon a white Body, but those that are cast upon it by another Body which has already modified them, the Rays will not be altered at all by the white Body, but reflected back to the Eye with the same Modification; so that the Body instead of appearing White, will appear of the Colour of that Body from which it received the Rays.

78. *A curious Experiment.* 78. We may be convinced of this by a very curious Experiment, which it is not very difficult to make. The Way of doing it is this. Let all the Windows of the Room be shut up close, except a very small Hole, through which the Rays reflected from the Objects on the outside, may enter in; then let the Rays fall upon a white Cloth, or any other white Body, and it is pleasant to see the different Colours of the Objects which are painted upon it.

79. *Why the Actions of different Objects transmitted thro' one and the same Place, do not destroy each others Effects.* 79. This Experiment perhaps may raise a Difficulty in the Minds of some, who may imagine, that different Rays, and differently modified, passing through the same Hole, must hinder one another, and confound their respective Actions: But it will not be hard to get clear of this Difficulty, if they consider in the first Place, the vast number of Pores that there is in the least Quantity of Air, or of any other transparent Body, which afford a Passage for an infinite number of Rays, if I may so speak, without disturbing one another. But that which is principally to be considered, and which takes away the Difficulty intirely, is, that the Light, or the Colours, do not consist so much in actual Motion, as in a Tendency to Motion, or a Pressure. Now it is easy to apprehend, that an infinite number of these sort of Actions, different from each other, may be transmitted through the same Point without confounding one another. For instance, suppose a Force equal to a hundred Pound Weight, applied to the Point A, of the straight Line AB, pushing it towards B, where we suppose also, that there is a Body able to resist this Force. The Line AB could not move at all according to the Direction of AB, much less can it bend towards C or D, because it is straight; but the least Force that can be, will bend it towards any Side whatsoever. Thus if any Force in C pushes it by E towards D, if it be but the Force of one Pound, it will bend it towards D: But if we suppose another Force in D which can resist that of a Pound,

Tab. V. Fig. 4.

this

this will hinder the Line AB from bending; ſo that the Force which is at A, ſhall tranſmit its Action whole and entire to B, without being diſturbed by the Force which is at C: And the Force which is at C ſhall tranſmit its Action to D, without the leaſt hindring the Continuance of the Action along AB. So likewiſe we may imagine a Force at F equal to five Pounds acting upon a Body at G. The ſame Point E therefore may ſerve to tranſmit as many Actions as we will, without at all confounding them.

80. After what I have already ſaid: I have but one Thing more to remark concerning the Diſtinction that is uſually made of Colours; *viz.* that ſome of them are *true* or *real* Colours, ſuch as thoſe of Tapiſtry, and others *falſe* or *ſeeming* Colours only, ſuch as thoſe ſeen through a Glaſs Priſm. But I don't ſee any Foundation for this Diſtinction, becauſe the Reality is juſt the ſame in each of them: For if the Senſation of Colour which we have upon viewing a Piece of Tapiſtry be real; that which we have in looking through a Priſm is as real; for the Priſm is as real a Thing as the Tapiſtry. And indeed it is the ſame Light which cauſes us to perceive the Colours through the *Priſm*, as cauſes us to perceive the other.

80. That Colours are not rightly diſtinguiſhed into true and falſe, real and apparent Colours.

81. If any one, in order to ſupport that Diſtinction of Colours which we have juſt now rejected, replies; that there is at leaſt ſome falſe Appearance in looking through a Priſm, becauſe we apply the Colours that we ſee, to Objects where they are not: To this I anſwer, that the Fault is not in our Sight, but only in the Judgement which we make afterwards. And if this were ſufficient to conclude, that theſe are falſe Colours; we may for the ſame Reaſon ſay, that all other Colours are falſe likewiſe, becauſe we equally falſely refer the Senſations which are cauſed in us by them, to the coloured Objects.

81. That we make a falſe Judgement of all Colours.

82. Nor have they ſucceeded any better, who owning all Colours to be equally real, have yet diſtinguiſhed them into *fixed* and *flying*; giving the Name *fixed* to thoſe which the other called *real*; and the Name *flying* to thoſe which the other called *falſe*: For if the Eye continue never ſo long applied to the *Priſm*, and during that Time the Light intervene in the ſame manner, we ſhall always ſee the ſame Colours; ſo that theſe are no leſs fixed and durable, than thoſe of a Piece of Tapiſtry.

82. That there is as little Reaſon for diſtinguiſhing Colours into fixed and flying.

83. That there is no Difference at all between the one and the other.

83. All the Difference that is to be found in the Objects that raise in us any Sensation of Colour, is only this; that some of them, such as the *Prism*, seem to require that the Eye should be fixed in a certain Place, out of which there is nothing to be seen; whereas others, such as Tapistry appear of the same Colour, which way so ever they are looked upon. However, if we consider the Matter a little more closely, it is certain, that the Prism, and the Tapistry, agree in this: that the same Parts of the Tapistry which reflect the Light to the Eye when it is in any certain Place, does not reflect the same to it, when it is removed ever so little out of that Place; and the only Reason why we perceive the same Colour when we change our Place is, because instead of these Parts, those Parts that are next to them, and which are exactly like them, reflect the Light in the same manner. If therefore the Eye were fixed in one certain Position, from whence it should see some particular Places of the Tapistry of some particular Colours, and God should annihilate all the other Parts of the Tapistry, so that they could not at all reflect any Light in the Place where the Eye is; it would continue to see the same Colours, but if it should change its Place, they would immediately disappear.

84. Of the Nature of changeable Colours.

84. This being well understood, there will be no great Difficulty in explaining those Colours which we call *Changeable*, such as we observe in a Duck's Neck, or in a Pidgeon, or in a Peacock's Tail: For it is easie to conceive, that the Parts of these Bodies are placed in such order, that those of them which are proper to modify the Light after one particular manner, are disposed to reflect it to one certain Place; and those that modify it in another manner, reflect it to another Place. Thus if the Eye be in the Place where the Rays come, which cause the Sensation of Red in us, then the Object appears Red, and if it be placed where the Rays which cause Yellow are reflected, the Object appears Yellow.

85. A Comparison of changeable Colours with Things made by Art.

85. This is confirmed from hence; that Workmen have found out a Way to make Stuffs of a changeable Colour, by making the *Warp* of a Light Colour, and the *Striking* of a Colour not quite so Light: But what most resembles the Objects to which we ascribe these changeable Colours, are those channell'd Tables which represent different Sorts of Things, according as they are viewed from different Places: For one of these Tables, when

it

it is looked directly upon, represents a *Cæsar's* Face; when looked upon on the Right Side, it represents a Cat, and on the Left Side a Skeleton. Thus, as they are different Parts of the Table which make these different Representations, so likewise are they different Parts of the Pidgeon which cause us to see different Colours.

86. The remaining Properties of Light and Colours cannot be understood, till we have explained the Nature of Vision.

86. If after what has been said concerning the Nature and Properties of Light and Colours, there remains any further Difficulty, it will be solved afterwards, when we have particularly examined the Nature of Vision: And this is what I shall proceed to; which I the more readily do, because the following Parts of this Treatise of Natural Philosophy, depend in some measure, upon Observations made by the Help thereof, so that it is necessary to know all the Circumstances of this Sort of Sensation, which is the most wonderful of any that we are possessed of: I shall begin with a Description of the Eye, and to avoid Tediousness, I shall mention only those Things which belong particularly to this Subject.

CHAP. XXVIII.

A Description of the EYE.

1. Of the Figure of the Eye. Tab. V. Fig. 5.

WHILST the Eye is inclosed in the Head of any Animal, the Bones which surround it, hinder us from seeing what Figure it is of; but when it is taken out, we find it is round, and such as is represented in the Figure ABCDEF. FABC is the fore-part of it, or that which sticks out; CDEF that part which is inclosed in the hollow Bone of the Head.

2. Of the Tunica Cornea.

2. AB is a transparent Part of that particular Coat of the Eye which is called the *Tunica Cornea*.

3. Of that which joins to it, or the White of the Eye.

3. BCDEFA is the rest of this Covering, the Parts of which that are next to A and B, are called *the White* of the Eye.

4. Of the Tunica Uvea, and the Pupil.

4. AILB is *the Tunica Uvea*, in which there is a Hole IL which is called *the Pupil.*

5. of the Ciliary Ligaments.

5. MN, MN, are certain black Filaments, which are called *the Ciliary Ligaments*; there is a certain soft and transparent Body called *the Chrystalline Humour* which is suspended upon them.

6. Of the Aqueous Humour.

6. The Space QQQ is filled with a transparent Liquor, which is very fluid like Water, and for that Reason is called the *Aqueous Humour*.

7. NONP

7. *Of the Chryſtalline Humour.* 7. NONP is a tranſparent Body of the Figure of a Lens, a little more convex on the Superficies NPN than on NON, which, becauſe it is a little hard, is called *the Chryſtalline Humour*.

8. *Of the Vitreous Humour.* 8. The reſt of the Cavity of the Eye RRR is filled with a ſlimy Matter, almoſt like the White of an Egg, which is more tranſparent than either the Aqueous or the Cryſtalline Humour, and is of middle Conſiſtency betwixt them, (for it can eaſier be compreſſed than the Chryſtalline, and yet it is not ſo fluid as the Aqueous Humour;) and this is called *the Vitreous Humour*.

9. *Of the Optick Nerve, and the Retina.* 9. DEGH is a Part of *the Optick Nerve*, whoſe Capillaments TS, beginning in the Brain, and reaching to the Eye, form at the Bottom of it a curious Piece of Network which Phyſicians call the *Retina*.

10. *That the Inſide of the Eye is black.* 10. I purpoſely forbear mentioning the Number and Names of the ſeveral Coats with which the Eye is covered, becauſe they are not of any particular Uſe in explaining the Nature of Viſion; but I muſt not omit to take notice, that the Superficies of theſe Coats are all Black in thoſe Places which are over-againſt the Bottom of the Eye.

11. *Of the Muſcles of the Eye.* 11. The whole Body of the Eye is encompaſſed with ſix *Muſcles*, four of which are called *Right*, and the other two *Oblique*. Every Nerve, which is thought to be the Original of the ſeveral *Right Muſcles*, is derived immediately from the Brain, from whence it comes along through a little Hole in the Bone of the Head, and divides it ſelf into theſe Muſcles, every one of which is inſerted into ſome Part of the Coat of the Eye, ſuch as that here marked F, in ſuch a manner, that of theſe four Muſcles, the Firſt is above, the Second below, and the other Two on each Side this Coat. And as the *oblique Muſcles* have their Origin alſo in the Brain, their Nerves are bent round, ſo that they ſeem to come from that Corner of the Eye which is next the Ear, and one of them ſpreads over the Top, and the other along the Bottom of the Eye, and ſo croſs the four right Muſcles, and then are inſerted into the Bone of the Noſe.

12. *The Uſe of the Muſcles of the Eye.* 12. There is no one Muſcle in the whole Body, but what is ſometimes filled with a certain Liquid like very thin and fine Air, which comes to it from the Brain along the Nerve which belongs to it. This Liquid is what Phyſicians call *the Animal Spirits*, which cannot ſwell the Muſcle without ſhortning it or leſſening the Length be-

twixt

twixt the Origin and the Place into which it is inſerted. Thus when the right Muſcle which is above, is filled with Spirits, the Eye muſt neceſſarily be lifted up, and when the Three other right Muſcles are filled in their Turns, they ſerve either to turn the Eye downwards, or to the Right, or to the Left Side. But what is very remarkable here, is, that if theſe four Muſcles be filled all at the ſame time, they will alter the Figure of the Eye a little, and make it flatter than it was before. But as to the oblique Muſcles, I am not of the ſame Opinion with thoſe Phyſicians who ſay that they ſerve to turn the Eye round like a Pulley: I rather think, that they are filled both together with Spirits, and by that Means ſhortned, and ſo they preſs upon the Eye and alter its Figure, in ſuch a manner, that the fore-part of it is made more gibbous, and the hinder-part ſunk a little deeper in; and this makes a greater Diſtance between the Chryſtalline Humour and the *Retina*.

13. To theſe Alterations of the Eye we may add, that the Pupil is capable of dilating and contracting it ſelf. And thus we find, that it dilates it ſelf, when we are in Places where there is but a little Light, and when we try to look at a great Diſtance; and on the other Hand, it contracts it ſelf when we are in a very light Place, or look at an Object very near. *13. That the Pupil is capable of being dilated.*

14. Laſtly, we may obſerve, that if the two *Optick Nerves* be purſued to the Origin of them, we ſhall find, that after they come into the Skull, they approach nearer and nearer to each other, till at laſt their Coats are mixed together, and they become one and the ſame; but afterwards they are ſeparated again, and then enter into the very Subſtance of the Brain, after which we ſee them no more. Wherefore to add any Thing further about this Matter, would have no Similitude of Truth, unleſs it were to account for certain Phænomena which otherwiſe could not poſſibly be explained. *14. Of the two Optick Nerves.*

CHAP.

CHAP. XXIX.

How Vision is commonly explained.

1. What is meant by Vision, *and that* Aristotle *has said nothing about it.* ARISTOTLE has said nothing in particular as to the manner how *Vision* is performed; for though the Title of the Seventh Chapter of his Second Book *of the Soul, concerning Vision,* seems to promise treating of this Matter fully; yet he says nothing more of it, but only this; that the Object must act upon the *Medium* in order to have its Action transmitted to the *Organ* of Sight. It is true indeed, that he says further in the Twelfth Chapter of the same Book; that in every Sensation we receive the *Images* of the Things, but not the Matter; in the same manner as Wax receives the Impression of the Seal, without retaining any part of the Seal it self; but here likewise, what he says is as general and loose, as what he said in the forecited Place; and the Comparison which he makes, does not at all show us how so great a Number of Parts of which the Object is composed, can be distinctly perceived at the same Time, nor how we can know the Situation, Distance, Bigness, Figure, Number, Motion or Rest of the Objects which are in our View.

2. The Opinion of the Aristotelians *about* Vision. 2. The Followers of *Aristotle* saw plainly, that he fell very much short of teaching what one would wish to know upon this Subject; and this has put them upon trying to find how his Doctrine was to be understood. Thus taking the Word *Image,* which he speaks of in the forecited Place, in the literal Sense; they affirm, that the visible Object impresses an Image upon the Air which surrounds it; that this Image impresses another a little less upon the Air beyond it, and this impresses a Third, a little less still, and so they go on till there is one impressed on the Chrystalline Humour of the Eye, which they pretend is the principal Organ of Vision, or that Part of the Body which the Soul makes immediate use of to cause Sensation. These are what they call *intentional Images* or *Species;* and in order to explain their Manner of Production, they say, that the Objects cause them in the same manner, as our own Image is produced in a Looking-Glass.

3. From

3. From what has been already ſaid, it ſufficiently appears, that I agree with *Ariſtotle* himſelf; but I can by no Means come in with his Followers in this Thing of their *intentional Species*, the Nature of which ſeems to me inconceivable, and has all along put their Underſtandings upon the Rack. And it is a mere Sophiſm to pretend to eſtabliſh their Opinion upon the Inſtance of a Looking-Glaſs, becauſe reflected Images are harder to be explained than direct.

3. That the Ariſtotelians *do not at all explain the Nature of their* intentional Species.

4. There is no need of mentioning all the Abſurdities conſequent hereupon, in order to ſhow that there is no ſuch Thing as *intentional Species*. It ſhall ſuffice only to obſerve; that if *They* are diminiſhed in the manner they ſay, it will follow, that when an Object is ſeen at ten Yards diſtance, the *Species* of it is only as little again, as when it is ſeen at five Yards diſtance; that is, an Object of ſix Foot in Length in the one Caſe, will appear of three Foot in Length in the other Caſe. Wherefore if the Eye and the Object be within five Yards of each other, it can receive but a very ſmall Part of ſuch a *Species*, and conſequently we could ſee but a very ſmall Part of the Object; but this is contrary to all Experience, for we can ſee ſuch an Object intire at ſuch a Diſtance, nay, at a much leſs. If they ſay, that theſe *Species* diminiſh otherwiſe when the Eye is nearer to them, than when it is further off; they muſt allow, that a Thing inanimate, and which acts neceſſarily, has however Underſtanding enough to proportion its Action ſo as to perform the ſame Thing at different Diſtances. Which being abſurd, it follows, that the Foundation upon which their *Species* is eſtabliſhed, is abſurd alſo.

4. The Abſurdity of theſe Species.

5. It is not only without Reaſon, but contrary to Reaſon, to affirm, *that Viſion is perfected in the Chryſtalline Humour*, and that the Vitreous Humour behind it, is of the ſame Uſe as the Quickſilver behind a Looking-Glaſs, *viz.* to terminate the Action of the viſible Object: For doubtleſs the Object ought to continue its Action thro' the Vitreous Humour, which being one of the moſt tranſparent Things that we know of in the World, cannot reaſonably be compared to Quickſilver, which is very opake. To this we may add, that ſince the Chryſtalline Humour is found in both Eyes, and two Species are formed by it at the ſame Time, if That were the principal Organ of Viſion, it would follow, that we muſt always ſee the Object double, when we look upon it with both Eyes at once.

5. That Viſion is not performed in the Chryſtalline Humour.

6. This

6. Neither is it performed in the Retina.

6. This last Reason shows also how false the Opinion of some Philosophers is, who affirm the *Retina to be the principal Organ of Vision.*

7. That it is not performed in the Place, where the Op- tick Nerves *meet.*

7. As to the Opinion of those who contend that this Sensation arises from hence, that *the Action of the Object is carried to the Place where the Optick Nerves meet;* this is confuted by the Experience of *Anatomists*, who have found these Nerves separated in the dead Bodies of some Men, who, when they were alive, saw Things in the same manner as others do.

CHAP. XXX.

Of the Passage of the Light through the Humours of the Eye.

1. How the antient Philosophers came to be mistaken upon this Subject of Vision.

I Think that most of those who have endeavoured to explain the Nature of Vision, have run into great Mistakes, principally from hence, because they attempted too many Things at a Time, and did not observe any Method or Order: Their Mistake will be a Help to us, if, upon observing, that Vision is a Consequence of the Action of the Object upon both the *external* and *internal* Organs; we, in the first Place, inquire, *how the Rays of Light, which are the Means by which any Objects are seen, are received by the Humours of the Eye.*

3. That it is sufficient to consider only some few of those many Rays which come from every Point of an Object. Tab. VI.

2. Let us suppose, for Instance, Z to be the Eye, and ABC the Object; there is no Doubt, but that every Point, that is, every the smallest visible Part of this Object, sends forth Rays all Ways through the Air, to every Place where it can be seen; but because those only which pass through the Pupil are of any use to cause Vision, we will examine those only which fall upon that Part of the *Tunica Cornea* which answers directly to the Pupil: Thus, in order to examine the Action of the Point B, it is sufficient to consider some few of the Rays which come from this Point, such as BD, BE, BF.

4. That some of the Rays go to the Bottom of the Eye without any Refraction at all.

3. Now because the Ray BD is perpendicular to the Superficies EDF, it will not be at all refracted in passing out of the Air into the aqueous Humour, wherefore it will continue on in a straight Line to H, where falling again perpendicularly upon the Superficies of the Chrys-

tal-

talline Humour, it muſt go on ſtill directly to M; and here falling again likewiſe perpendicularly upon the Superficies of the Vitreous Humour, it muſt go directly to the Point O in the Bottom of the Eye.

4. Of the Refraction of ſome other of the Rays, and how they which come from one Part of an Object, meet again in one Point in the Retina.

4. But the Ray BE not falling perpendicular upon the Superficies EDF, where it is to paſs out of Air into Water, it ought to be refracted, and to go towards the Perpendicular EP, and conſequently it will tend to ſome Point of the Superficies of the Chryſtalline Humour, ſuppoſe G, which is ſomewhat nearer H, than it would be without ſuch Refraction: Again, the Ray EG likewiſe, not being perpendicular to the Superficies GHI, through which it is to paſs out of the Aqueous Humour into a denſer *Medium*, it ought to be refracted again, and go towards the Perpendicular GR, and conſequently to arrive at ſome Point of the Vitreous Humour, as L, which is nearer to M than if there had been no Second Refraction: Laſtly, Becauſe the Ray GL is alſo inclined to the Superficies LMN, through which it is to paſs from a denſe *Medium* to one this is much rarer, it muſt be refracted, and go from the Perpendicular LT, the Poſition of which is ſuch, you ſee, that the Ray, by going from the Perpendicular, approaches towards the Ray BDO; and we may conceive it refracted in ſuch a manner, that it ſhall go to the ſame Point that the Ray BDO went to, that is, to the Point O. So likewiſe if we conſider the Ray BF, we ſhall find that the Refractions will carry it from F to I, and from I to N, and that at laſt it will meet the other Two at O. And ſince the Rays which fall betwixt BE and BF, are not quite ſo much refracted as they themſelves are, it is evident, that they cannot do otherwiſe than meet all together in the ſame Point O. Thus we ſee, that the Point B acts upon the Bottom of the Eye, in the ſame manner, as if the Pupil were of no Breadth, and as if there were to come but one Ray with a Force equal to the Forces of all them that are contained between BE and BF.

5. That the Rays which come from different Points of the Object, fall upon as many different Points of the Retina.

5. Now if we conſider the Rays which come from any other Point of the Object, as from A, we ſhall find, that all thoſe which enter into the Eye, will be refracted in ſuch a Manner, as almoſt to meet all together in the ſame Point X. And ſo likewiſe thoſe Rays which come from any other Point between A and B, will meet very near together in ſome Point of the Bottom of the Eye between X and O. So that we may affirm in general, *That every Point of the Object, acts very near-*

ly

ly but upon one and the same Point in the Bottom of the Eye; and on the other Hand, *That every Point of the Bottom of the Eye receives very nearly the Impression of one Point only of the Object.*

6. That the Rays which come from some Points, do not reunite so exactly as those which come from some other Points.

6. I say very nearly, not exactly. For if the Superficies EDF, GHI, LMN, were of such a Curvature, as to carry the Rays from one single Point, such as B, to another single Point such as O, exactly; it would be impossible for them to unite the Rays which come from any other Point such as A, because every other Point is differently situated from B with respect to the Eye.

7. That if the Eye could no way be altered, the Refractions could not reunite upon the Retina *the Rays which come from Objects at all Sorts of Distances.* Tab. VI.

7. Now we may observe, that if the Object be removed further from the Eye, in such a manner that the Point B continues always in the Line BD, and the Shape or Disposition of the Eye be no ways altered; the Rays which come from the Point B to the Pupil, will not diverge so much, or be at quite so great a Distance from each other as they were before; wherefore in entring the Three Superficies EDF, GHI, LMN, they will be refracted in such a manner, as to reunite a little nearer to the Chrystalline Humour than the Point O is. On the other Hand; if the Object be removed nearer to the Eye: because the Rays which come from the Point B in order to pass through the Pupil, diverge more than they did, their Refractions will cause them to meet beyond the Point O. And the Object may be so very near the Eye, that the Rays which come from any one of the Points, may diverge so much, as never to unite at all. In all which Cases, 'tis plain, there would be no one Point of the Object, that would not effect too large a Portion of the Bottom of the Eye; and consequently the Action of each Point, would be confounded by that of the Point which is next unto it.

8. Of the Alteration made in the Eye, in order to reunite them.

8. This is what would happen, if the Figure of the Eye could not be altered; but to remedy all these Inconveniencies Nature has so formed the Eye, that it can become flatter or longer to such a Degree, as to adjust it self to the different Distances that we would view the Object at. Wherefore when we would look upon an Object at a greater Distance than it could be seen distinctly at when the Eye is of the usual Figure, it is then made flat by the Help of the four right Muscles, all which acting together, pull it towards the Bottom of its Ball, and the *Retina* is by this means near enough to the Chrystalline Humour, to be exactly in the

the Place where all the Rays which come from any one Point of the diftant Object are reunited. And when we would look upon an Object that is very near, the Eye is lengthened by the Help of the oblique Mufcles which encompafs it, and by being fwelled, comprefs it; and then the Diftance between the Chryftalline Humour and the *Retina* becomes greater, that the Rays which come from any fingle Point of the Object which is fo near, may be reunited in a fingle Point upon the *Retina*. If, therefore, there remains any Confufion which Nature has not provided a Remedy for, it is only in refpect to the Action of thofe Rays which come from an Object that is too near the Eye, at two or three Inches diftance, fuppofe; but this is needlefs, or at leaft, not neceffary to be remedied; for as Sight was given us principally to take Notice of Things at a Diftance, and there is very feldom any Occafion for feeing Objects fo very near, Nature has not provided for it.

9. This Approaching and Receding of the Chryftalline Humour with refpect to the Bottom of the Eye, is fo neceffary in order to fee diftinctly, that becaufe it cannot be performed by Mufcles in fome Birds, the Coats of whofe Eyes are almoft as hard and inflexible as Bones, Nature has provided another Way. For there are placed in the Eyes of fuch Birds certain black Filaments, that are not in the Eyes of Men or other Animals, by which the Chryftalline Humour is connected with the Bottom of the Eye, and by which it can be made to draw nearer to, or remove further from the *Retina*. *9. The the Eyes of Birds are altered in a different manner.*

10. It is obfervable, that the firft of the three Refractions which the Rays of Light undergo, in paffing thro' the Humours of the Eye, is not to be found in Fifhes who live in the Water, becaufe the Rays are already in an aqueous *Medium*, when they begin to enter into the Eyes of Fifhes. And this feems to be a Reafon why the Want of this Refraction fhould be compenfated fome other Way. And fo we find it is; for Nature has made the Chryftalline Humour of Fifhes Eyes more convex, infomuch, that it is almoft as round as a Globe, and not of the Figure of a Lens, as it is in other Animals. *10. A remarkable Obfervation of the Eyes of Fifhes.*

11. As moft antient Perfons grow lean and thin by Age, fo their Eyes grow flat and more funk than when they were younger. Now in this Figure of the Eyes, the Rays which come from an Object very near, come to the *Retina* before they are reunited; wherefore they imprefs but a confufed Image upon it; fo that it is impoffi- *11. That the Images of Objects that are near, is very confufed in old Men.*

ble for such Sort of Eyes to receive any distinct Image, except when the Object is at a sufficient Distance.

12. That those Eyes which are very large and stick out, receive only a confused Impression of Objects that are at a Distance. 12. On the other Hand, some Persons have by Nature Eyes that are longer and more gibbous than those of other Men; in which the Distance betwixt the Chrystalline Humour, and the Bottom of the Eye, is likewise greater than usual: In these, the Rays which come from one Point of an Object further off than ordinary, are reunited also, before they come at the *Retina*, and then are separated again, so that they spread themselves a little upon the Bottom of the Eye. Whence it comes to pass, that these Sort of Eyes can receive only a confused Image of Objects that are at a Distance; and have a distinct Image of those only that are near.

CHAP. XXXI.

What we mean, when we say, that the Images of the Objects are impressed upon the Organs of Sight.

1. That perfect Images of visible Objects are impressed on the Retina. WHEN we once clearly understand, that every single Point of the Object acts upon one single Point only of the Bottom of the Eye which answers directly to it; and on the other hand, that every Point of the Bottom of the Eye receives the Impression of but one Point only of the Object; it is not difficult to conceive that the whole Object acts upon a certain Part of the *Retina*, which is as exactly of the same Shape with it, as could be drawn upon a Cloth by the most skilful Painter. We can yet further conceive, that this Part of the *Retina* does still more perfectly resemble the Object, because it receives as many different Pressures in all its several Parts as there are different Colours, or different Degrees of Light in the several Parts of the Object. And because we call that an *Image*, or a *Species*, which has any Resemblance to the Thing which it represents, we call that Part of the *Retina* upon which all the Rays of the Object fall by that Name, and say, *That it impresses its Image on the Bottom of the Eye.*

2. There

2. Wherein this Image is different from the Object.

2. There is no need of searching after any other Resemblance in this Image, than what has been mentioned. For if we would make any further Comparison betwixt it and the Object, we shall find them very different. And first, herein they differ, that a Body is always represented by a Superficies, and sometimes a Superficies by a Line, and sometimes a Line by a Point: Secondly, The Situation is different, for the upper Part of the Object is painted upon the lower Part of the Eye, and the right Side of the Object upon the left Side of the Eye, *&c.* Lastly, They differ in Magnitude, for a very large Object is represented upon a very small Part of the Eye.

3. The further the Object is distant from the Eye, the lesser is its Image. Tab. VIII. Fig. 1.

3. And the further distant the Object is, so much the less is this Part of the Bottom of the Eye; as is evident in the Figure of the Eye C, where the Space HI, which receives the Image of the Object FG, is less than the Space DE on which the Object AB, which I suppose equal to FG, is impressed; and this very nearly in the same Proportion, as the Distance of FG from the Eye is greater than the distance of AB.

4. An Experiment whereby these Images may be seen.

4. Whoever considers ever so little of what we have before laid down, concerning the Nature of Light and Colours, cannot but be of our Opinion, *That the Images of Objects are in this manner impressed on the Bottom of the Eye:* But he may be further convinced of it from Experience; for if, [illegible] all the Windows of a Room, over-against which are [illegible] Objects, we make a Hole in the Window-Shut, and place in it the Eye of an Animal, fresh killed, first taking off neatly all the Membranes which the Bottom of the vitreous Humour is covered with, and put an Egg-Shell in their stead to hold this Humour in, we shall see upon the Egg-Shell a distinct Picture of all the Objects that are without.

5. An artificial Eye for the same purpose.

5. But because there are some Difficulties to make this Experiment succeed well; I have thought that the same Thing might be done, by making a large artificial Eye, which I accordingly tryed: The opake Coats, or Tunicks, were all made of thick Paper, except the *Retina*, which was made of a very white thin Piece of Vellum; in the Room of the *Tunica Cornea*, I put a transparent Glass, and instead of the Chrystalline Humour, was a Piece of Chrystal of the Figure of a Lens, but more flat than this Humour; for since there was nothing in this Machine but Air, in the Places of the aqueous and vitreous Humours, a little less Convexity was sufficient to produce

the Refractions required: And because it was very difficult to flatten or lengthen this artificial Eye, in the manner the natural Eye is done by the Muscles, I placed the Vellum in such a manner, that it could be moved backward or forward, at Pleasure.

6. How to see the Image of an Object in this artificial Eye.

6. This artificial Eye being so placed in the Window of a Room, that the Glass which represents the *Tunica Cornea*, may be directly against some Objects that are very much illuminated; we shall not only see the the Images of them impressed upon the Vellum, but we may also observe all the most minute Particularities, which we before collected from Reason. Thus we may observe,

7. The first Observation.

7. *First*, That it is at one particular Distance only of the Vellum from the Chrystal Lens, that the Image will appear the most distinct that is possible.

8. The second Observation.

8. *Secondly*, That this Image is not so distinct in the extreme Parts, as in the Middle.

9. The Third Observation.

9. *Thirdly*, That if the Vellum be too near the Lens, the Image will be less, and very much confused.

10. The fourth Observation.

10. *Fourthly*, That if it be too far, the Image will be larger, but all confused likewise.

11. The fifth Observation.

11. *Fifthly*, That the distinct Image of any Object, is so much the less, as the Object is more remote.

12. The sixth Observation.

12. *Sixthly*, If a certain Distance between the Lens and the Vellum, be requisite to make a distinct Image of an Object at a moderate Distance; the Vellum must be moved a little nearer, so that the Distance of the Lens from it may be less, if we would have a distinct Image of another Object, which is at a considerably further Distance.

13. The seventh Observation.

13. *Seventhly*, When the Vellum is at a proper Distance, to represent distinctly an Object which is at a great Distance, suppose an Hundred, or Two hundred Yards; there is no need of altering it, in order to represent, as distinct as is possible, any Objects that are at a still greater Distance.

14. The eighth Observation.

14. *Eighthly*, The nearer the Object is to this artificial Eye, the further must the Vellum be removed from the Lens.

15. The ninth Observation.

15. *Ninthly*, When the Object is too near this artificial Eye, it is impossible to get any distinct Image, let the Vellum be removed to what Distance we will.

16. It

16. The difference betwixt this artificial Eye, and the natural Eye.

16. It is to be obferved, that in thofe Cafes where any Alteration muft be made in the Eye, in order for the Image to become diftinct, this Alteration is much lefs in the Eyes of Animals, the Coats of which are flexible, than in this artificial Eye. For in Animals, the lengthning or fhortning the Eye being always attended with a greater or lefs Convexity of the Cornea, the Figure of this Coat contributes its Part in producing that Effect which in the artificial Eye wholly depends upon the Length or Shortnefs of it. Thus, if when the artificial Eye has received a diftinct Image of a diftant Object, another Object be placed before it at fuch a nearer Diftance, that in order to have the Rays which come from every Point of it reunited, the Eye ought to be made One hundredht Part longer than it is; the Vellum muft be removed juft fo much further from the Lens: But in a parallel Cafe of the natural Eye, it is not requifite that *That* fhould be lengthned a hundredth Part of the Whole, becaufe the *Tunica Cornea* being more gibbous than it was before, caufes greater *Refractions*, and fo makes the Rays reunite fooner than they would otherwife do.

17. That the Capillaments of the Optick Nerves, tranfmit the Action of the Object to the Brain.

17. The Image of an Object impreffed on the Eye of an Animal, being received in a Place where the Capillaments, of which every Optick Nerve is compofed, meet each other; it is very probable, that this Image is fo impreffed, that the Rays do not move thefe Capillaments fide-ways, but always fall directly upon the Extremities of them. To which, if we add; That the Impreffion which is made upon the Extremity of every one of thefe Capillaments, is communicated from one End to the other, we may conclude, that the Image of the Object is tranfmitted intire to that Place where thefe Capillaments end in the Brain.

18. That the Brain is the Place where the Soul perceives.

18. And becaufe we have no Senfation, when thofe Parts of the Body are any way affected, in which there are no Nerves; it is very probable, that the Nerves are neceffary to Senfation. And becaufe we have no Senfation likewife, when any Object makes an Impreffion upon a Nerve, if its Communication with the Brain be hindred, or if the Brain it felf be affected with any particular Diftemper; therefore it is reafonable to think, that the Nerves are not the immediate *Organs* of the Soul, but that they are fo formed by Nature, as to tranfmit the Impreffion which they receive, to that Place in the Brain where the Origin of them is, and where probably the immediate Organ of the Soul's Senfation is.

19. That there is a Part of the Brain which is the principal Organ of the Soul.

19. However, we may further obferve, that there being Two of a Sort of almoft all the Parts of the Brain, they cannot all of them indifferently be thought the immediate *Organ* of the Soul. On the contrary, it is highly probable, that fince we have but one Senfation only, though two Impreffions are made by the Object upon the external *Organs* of the Senfes which are affected, that there is likewife one particular Place in the Brain where thefe two Impreffions meet. Which that Place is, may be very difficult to determine; but whether it be that fmall Gland which Phyficians call the *Conarium*, or whether it be any other Part of the Brain, it is hardly to be conceived how they can thus unite, without fuppofing fomething equivalent to what is now faid.

20. A Conjecture about the Continuation of the Capillaments of the two Optick Nerves. Tab. VII. Fig. 2.

20. Befides the manifeft Refemblance which there is betwixt the two Eyes; I imagine there is another yet, which cannot be difcerned by the Senfes, which confifts in this, that the Number of Capillaments in one *Optick* Nerve, is equal to the Number of Capillaments in the other Optick Nerve. Thus (to make the Thing eafier) if we fuppofe the *Optick* Nerve of the Eye A to contain five Capillaments, the Extremities of which are CDEFG; it is reafonable to think, that there is the fame Number in the Nerve of [illegible]mities of which are HIKLM. I imagine alfo, that the Extremities E and K, which are in the Middle of the Reft, are exactly at the End of the *Optick* Axes, that is, at the Ends of the Lines TE, VK, which pafs through the Centers of the Pupil, the Chryftalline Humour, and the Body of the Eye; and that the reft are placed fo regularly about thefe, that we may take feparately all the Capillaments of one Eye in order, and affociate them with thofe in the other Eye taken in the fame Order, fo as to make up a great Number of Pairs, which may be called *Sympathetick*: Thus beginning with the Capillaments C and H, which are moft on the Left Hand, I make them the firft Pair; the other Pairs are DI, EK, FL, GM. I am alfo of Opinion, that each Pair of *Sympathetick* Capillaments end in [1] the fame

1. *In the fame Point of that Part of the Brain*) This Conjecture is not yet confirmed, by cutting open the Brain. But be that as it will; the Capillaments CH, DI, EK, &c. may very properly be called *Sympathetick*. (Tab. VII. Fig. 2.) For whether the Pairs of Nerves meet in the Brain or no, it is evident, that two Images of every Object impreffed upon thofe Capillaments muft be feen in the very fame Place (becaufe the Optical Axes meet each other) that is, muft become one; and therefore the Object appears fingle.

ſame Point of that Part of the Brain which raiſes a Senſation in the Soul; as you ſee in the Figure, where the Pair CH meet in the Point O of the principal *Organ* X, the Pair DI in the Point P, the Pair EK in the Point Q, the Pair FL in the Point R, and the Pair GM in the Point S.

21. This being ſuppoſed, I conceive that when we would look upon an Object, we turn our Eyes to it in ſuch a manner, that the two *Opticks* Axes meet at the Point which we fix our Attention principally upon. Thus the Rays TE, VK, coming from that Point, and falling upon the *Sympathetick* Capillaments E and K, the two Impreſſions which they make there, are reunited in one Point only, *viz.* in the Point Q. So likewiſe the Part of the Object which is on the right Hand, ſhakes the *Sympathetick* Capillaments D and I, the Impreſſions of which are carried to P. And again, the Part of the Object which is on the left Hand acts upon the *Sympathetick* Capillaments F and L, and their Impreſſions unite in the Point R, and ſo of the reſt. So that though there be two Images impreſſed upon the Eyes, yet there is but one impreſſed upon that Part of the Brain X which we here ſuppoſe to be the immediate *Organ* of Viſion.

21. How the Object acts upon the immediate Organ of the Soul. Tab. VII. Fig. 2.

22. What has been already ſaid of the Images which viſible Objects impreſs upon the Eyes being well underſtood; it cannot but be a ſtill greater Surpriſe, that the *Ariſtotelians* and almoſt all Phyſicians ſhould be ſo miſtaken, as to affirm, that theſe Images are impreſſed upon the Chryſtalline Humour, and go no further; for it will evidently appear, that the different Impreſſions of the diverſe Points of the ſame Object, are all confuſed there.

22. An evident Proof, that the Chryſtalline Humour is not the immediate Organ of Viſion.

CHAP. XXXII.

How Vision is performed.

1. What is meant by Vision.

AFTER having traced the *material* Image of the Object, or the *Impression* which it makes upon the external Organs, to the Brain, I come next to explain how this raiſes in us an *immaterial* Image, or that Senſation in which Sight properly conſiſts, and to ſhow the Reaſons why it is *clear* and *diſtinct*; and alſo how we perceive the *Place, Situation, Diſtance, Magnitude, Figure, Number,* and *the Motion or Reſt* of ſuch Objects.

2. How the immaterial Image of the Object is formed in the Soul.

2. In order to underſtand how this *immaterial* Image is formed in us, I muſt remind you of a certain Truth which has been ſufficiently demonſtrated before; and that is, That ſuch is the Nature of our Soul, that particular Motions of the Body to which it is united, are the Occaſions of particular Perceptions in it: Now different Parts of the Object, act diſtinctly upon different Parts of the Bottom of the Eye, and their Impreſſions being tranſmitted to that Place of the Brain which is the principal *Organ* of the Soul, it is eaſy to apprehend, that the Soul muſt have as many diſtinct Senſations raiſed in it, at the ſame Time, and without any Confuſion, as every one of them excites different Motions.

3. Whence it is that this Image is ſo clear.

3. It is manifeſt alſo, that this immaterial Image, ought to be ſo much the more *vivid* or *clear*, as the Object ſends forth more Rays of Light which are received by the Eye; for by this means the Impreſſion made upon the Organ will be ſo much the ſtronger. And the Largeneſs of the Pupil contributes likewiſe to this *Clearneſs*, becauſe it affords Room for more Rays that come from the ſame Point of an Object to impreſs the Image on the Bottom of the Eye.

4. That the Image of a Body at a Diſtance ought to be as clear as that of a Body which is near.

4. It is true, that if we conſider the Action of one Point of the Object only, we muſt ſay, that the Senſation ought to be weaker or more obſcure in proportion to the greater Diſtance of the Body, becauſe the Rays of Light which come from one Point of it diverge, and therefore fewer of them enter into the Pupil when the Eye is far off, than when it is near. But we know that one Point of the Object does not act alone, but always acts in company with a great many others, and the whole Image of the

the Object is impreffed upon fo much a lefs Space on the *Retina*, as the Diftance of the Object from the Eye is greater. Thus if one vifible Point, at the Diftance of two Miles, fend to the Pupil but half the Rays that it would do if it were but at a Mile diftance only, this is made good by fome other vifible Points that are near it, which fend their Rays upon the fame Capillament of the *Optick* Nerve, where one fingle Point of a nearer Object would fend its Rays; wherefore the Vifion ought to be as *ftrong* and *vivid*.

5. To this we may add, that becaufe we open the Pupil of the Eye a little more when we look upon Objects that are at fome diftance, than when we look at thofe which are near; therefore we take in more Rays from any Point than we do when the Pupil is not fo wide, and this makes the Senfation more clear. And thus we find, that a Mountain looked upon at fome diftance does not appear of fo dark a Colour as when we are nearer it. *5. Why diftant Objects appear more clear to us.*

6. As to the *Diftinctnefs of Vifion*, that evidently depends upon the Refraction of the Rays; and it is then as diftinct as poffible, when the Refraction is fo made, as that all the Rays which come from one and the fame Point of the Object, meet together exactly in one and the fame Point of the Bottom of the Eye: But this never is precifely fo, but in thofe Rays which come from that Point of the Object which is at the Extremity of the *Optical* Axis; for it is evident, that thofe Rays which come from the other Points, are reunited fo much the lefs exactly one than another, as they are more diftant from this Axis; wherefore we cannot at the fame time have the moft diftinct Senfation but in this Place alone, and the reft will be more confufed. *6. How Objects appear diftinct.*

7. This being fo, it follows from what was before demonftrated concerning the confufed Impreffion of an Object that is near, on the Eye of an Old-Man; that he muft fee fuch a near Object very confufedly; and thus we fhall efcape the Error of thofe, who are of Opinion, that the Confufednefs in the Sight of Old-Men, arifes from hence; that the *Faculty of Seeing*, or the *Senfe of Seeing* is weaker in them than in others. And indeed it is very furprizing, and very lucky, that at a time when the Doctrine of Refractions was not at all known, *Ariftotle* fhould hit upon faying, that if an old Man had the Eye of a young Man, he would fee as the young Man does; which is the fame Thing as to fay; that the Fault *7. Why old Men fee Objects that are near them very confufed.*

Fault in the Sight of an old Man, does not arise from any Defect in the *Faculty of Seeing*, but only from some Defect in the *Organs*.

8. Why some Persons see Objects that are at a Distance confusedly.

8. On the other Hand we are assured, that those Persons, whose Eyes are longer and more gibbous than ordinary, receive a distinct Impression only of those Objects which are near; and a confused Impression of those that are distant: Whence it is easy to conclude, that such Persons must see Objects that are near them distinctly, and those that are at a Distance confusedly.

9. Another Cause of the Distinctness of Vision.

9. The *Distinctness* of Vision depends also upon the Largeness of the Space which the Impression of the Object takes up in the Bottom of the Eye, where there ought to be at least as many Extremities of the Capillaments of the *Optick* Nerve, as there are different sensible Parts in the Object which sends forth the Rays, in order for every one of them to make a distinct Impression. For if the Rays which come from two different Parts of the Object, meet together in two different Points of the same Capillament, it is the same Thing, as if they met in one Point, because they cannot communicate two different Motions to this Capillament at the same time. And this is the Reason why Objects, that are at a very great Distance, because their Images are impressed on a less Space, are seen but confusedly.

10. Why Objects, whose Parts are of different Colours, appear at a Distance of the same Colour.

10. Further, if this distant Object be composed of a great many different Parts which are of different Colours, it is evident, that if several of these Parts act together upon the same Capillament, that which is of the brightest Colour is the only one that will be seen, because the Capillament will receive the Impression only of this Part. And thus we see that in a Meadow where there are a great many white Flowers mixed with a vast Number of green Spires of Grass, at a Distance it looks all White.

11. How we refer our Sensation to external Things.

11. If it had never been observed, that we sometimes have no Perception, when we would have some, and at other Times have a Perception, when we would not, we should not have been so ready to have connected our Judgement with our Sensation, and Sensation would only have been simple Perception: But when we had once made this Reflexion, our Sensation must necessarily be a compound Perception: And if we had been more wary in our Judgement at first, so as not to have assented to any Thing of which we had not a clear Perception, all that we could plainly have inferred, is, that something concurrred with us to cause Sensation. But having been dis-

ently accuſtomed from the Beginning, and over-haſty our Judgement, we have drawn a different Conſe-nce; and look upon the Senſation, which now upon ore mature Deliberation, we acknowledge only as an cidental Mode of exiſting, to be *without us*, and there-re we refer it to *external Objects*; and we have ſo of-n made this Judgement, that we are accuſtomed to do without any Difficulty, and without the leaſt Suſpicion f its not being conformable to Truth.

12. We have been confirmed in this Errour about *Vi-on* by another Miſtake. We obſerve, that when an pake Body is put between the Object and our Eye, we en ceaſe to ſee it: From whence we ought to con-lude, that the Thing which concurs with us to excite enſation, is beyond the opake Body, and being no longer ble to act upon our *Organs*, we ceaſe to have the Sen-tion we had before. But inſtead of reaſoning in this anner, we imagine, that the Senſation which we have f Light or Colour, that is, the Light or Colour which we perceive, is beyond that Body, and ſo carrying our magination as far as the Object itſelf, we go as it were out of our ſelves, along the Line in which we eceive the Impreſſion of the Object, and aſcribe our own Senſation to it, that is, the Colour which we per-ceive. *12. Another Reaſon why we do this.*

13. The ſame Thing that leads us to refer the whole Senſation which we have of an Object to ſomething without us, leads us alſo to refer all the particular Senſations of which it is compoſed, in the ſame manner, in ſtraight Lines, according to the Direction in which we receive the Impreſſions from different Parts of the Object: Thus the Impreſſion which is made in the lower Part of the Bottom of the Eye, coming to us in the higheſt of all the Lines by which the Object raiſes any Senſation in us; it is along this Line that we refer the particular Senſati-on which ariſes from it. So likewiſe we refer to the loweſt Part of the Object, that Senſation which ariſes from the Impreſſion made by it, on the higheſt Part of the Bottom of the Eye. And hence it is, that though the whole Image which the Object impreſſes on the Bottom of the Eye be inverted, yet when we look upon the Ob-ject through a ſimple uniform *Medium*, this hinders not but that it appears in its true Situation; that is, the immaterial Image makes the Object appear to us as it is. *13. How we perceive the Situation of an Object.*

14. The

14. How we perceive its Distance.

14. The Knowledge of the *Distance* of an Object, as well as that of the Situation of it, depends upon our referring our Senſation to ſomething without us. For our regard being chiefly upon the Poſition of the two *optical* Axes; and the Motion of the right Muſcles of our Eyes by a natural Way of Reaſoning, ſhowing us very nearly, the Relation or Inclination which theſe two Axes have to each other, and at what Diſtance from us they meet together; it is to this Diſtance that we refer our Senſation, that is, to the ſame Place where the Object is. Wherefore if at any Time we are deceived in the Judgement we make of the Diſtance of any Object when we look upon it with both Eyes, it is becauſe we do not know exactly at what Diſtance the *Optical* Axes meet.

15. Another Way to know the Distance of an Object.

15. And if we make uſe of but one Eye, we can know the *Distance* of an Object; provided we move from one Place to another; for we have ſome kind of Memory of the Poſition of the *Optical* Axis in the firſt Station, when we really attend to the Poſition of it in another Station; ſo that we imagine two *Optical* Axes, though there be indeed but one, and by that means gueſs at the Diſtance where they meet; and to this we refer the Object.

16. A Third Way to know the Distance of an Object.

16. Since we cannot incline the *Optical* Axes to each other in a certain manner, in order to make them meet at one Point of an Object which is at a certain Diſtance from us, but at the ſame Time we muſt put each Eye into a particular Diſpoſition or Figure, neceſſary to ſee diſtinctly at that Diſtance; we may preſume that Nature has ſo ordered the Muſcles of the Eyes, that they neceſſarily procure both theſe Effects at the ſame Time: And that this is ſo, we ſhall have no Doubt, if we obſerve, that they who ſee but with one Eye, move their Eyes in the ſame manner to look upon Objects at different Diſtances, as they who ſee with both Eyes. So that it is ſufficient, if our Eye be ſo flattened or lengthened in a particular manner by the Action of the Muſcles, as to cauſe ſome Alteration in the Brain, which puts the Soul upon conceiving the Poſition of the *Optical* Axes: And ſince the perceiving this Diſpoſition is the moſt natural Argument to make us know the Diſtance of an Object, it follows, that the lengthning or flattening the Eye is alone ſufficient to diſcover this Diſtance.

17. But becaufe the Alteration of the Shape of one Eye only, when we make ufe of it to fee diftinctly at different Diftances, is not fo fenfible, as the Alteration of the Situation or Pofition of the two Eyes, when in order to look at different Diftances we turn them differently, that we may make the two *Optical* Axis meet in the fame Point; therefore we are not to think, that this latter Alteration is fo exactly made, when it is determined by the other, as if it were caufed by that Attention which we have when we look with both Eyes upon the fame Point of an Object. And this is the Reafon why we are more apt to be deceived in the Judgement we make of *Diftance*, when we ufe but one Eye than when we ufe both. And indeed if we try to touch [1] an Object at three or four Foot diftance, with the End of a Stick of about the fame Length, we fhall find, that if we look at it but with one Eye, we fhall mifs touching it two or three times together; whereas if we look at it with both Eyes, we fhall touch it the firft Time.

17. That it is eafier to be deceived in the Judgement we make of the Diftance of an Object, when we look upon it with but one Eye, than when we look upon it with both Eyes.

18. Whatever the Alteration be, which is made in the Eyes when we look upon Objects at unequal Diftances, it is certain, that That Alteration cannot be at all fenfible, when the Diftance is fuch, that the neareft Object is a great Way off; wherefore we muft be very liable to be more deceived in our Judgement of great Diftances than of fmall.

18. That it is eafier for us to be deceived in our Judgement of great Diftances than of fmall.

19. Befides the two forementioned Means of judging of the Diftance of Objects, which are the principal ones, there is yet fome others: As Firft. Having often obferved, that an Object appears more confufed the further it is diftant from us, we make this a Rule of determining the Diftances of Bodies, fo that according as they appear more or lefs confufed do we imagine them to be at a greater or lefs Diftance.

19. That the Diftinctnefs or Confufednefs of the Images of Objects, help us in judging of their Diftance.

20. So likewife, becaufe we have often obferved, that an Object looks of a brighter Colour, the further it is removed from us; therefore when we fee an Object of a brighter Colour than it ufes to appear of when it is near; we conclude, that it is at a great Diftance from us.

20. The fame Thing alfo follows from their being more or lefs bright.

1. *An Object at three or Four Foot Diftance*) is to be obferved, that the Stick muft not be thruft directly upon the Object, but moved obliquely, in the fame manner, as if, when a Ring is turned Side-ways to the Eye, we would try to run a Stick through it; as is juftly remarked by *Malbranch in his Enquiry after Truth. Book* I. *Chap.* ix *Sect.* 3.

21. The

21. *That we know the Distance by the Situation also.* 21. The Situation is another Means ftill of knowi the Diftance of Objects. For, of thofe Things whi we imagine to be lower than our Eye, we judge them be fartheft diftant which affect the Eye with the high Rays; and on the other Hand, of thofe Things whi we imagine to be higher than our Eye, we judge the to be fartheft diftant which affect the Eye with the lo eft Rays.

22. *The Interpofition of a great many other Bodies, makes us think, that the Object is at the greater Diftanse.* 22. Further, the Interpofition of a great many oth Objects between us and the Object we look at, mak us think, that the Diftance is greater than otherwi we fhould; becaufe the Diftance which we concei to be betwixt every one of them, is the Meafure whi we compute the Diftance of the Object by: Th in the Inftance of the Moon, when it is at the *high* above the Horizon, and we look at it through t Air only in which there are no other vifible Objec we imagine it to be nearer to us, than when it *rifes* *fets*; becaufe at thofe Times, there are a great ma intermediate Objects upon the Earth, betwee and it.

23. *How we come to know the Bignefs of Objects.* 23. When we know the Situation and Diftance an Object, by joining thefe together, we form a Judg ment of the *Bignefs* of it; For, becaufe we imagine th Extremities of an Object, to be contained between tw ftreight Lines [illegible] e, which diverge fro each other in proportion to their Diftance; therefor we eafily conceive what the *Bignefs* of the Object is a given Diftance. So that if at any Time we are de ceived in our Judgement of the Bignefs of any Objec it is becaufe we are firft deceived in our Notion its Diftance. Thus, becaufe we cannot truly compre hend the Diftance of the Moon or Sun from us, there fore no Imagination can reprefent thofe Bodies to us f great as they really are.

24. *Why the Stars feem bigger to us when they are in the Horizon.* 24. And this is fo true, that the Stars feem to u fomewhat larger, when the Interpofition of vifible Ob jects which are between them and us, helps us to ima gine their Diftance to be greater; For it is not ow ing [1] to the Interpofition of Vapours, as the Ancien though

1. *To the Interpofition of Vapours,* &c.) Since the Angle under which the Moon appears when in the Horizon, is not greater than ordinary, it is evident, that nothing ought here to be afcribed to the Refraction of the Vapours. An that this Angle is not greater th ordinary, is clear from hence; th though every particular Part of th Horizon (as well the Diftances the Stars from each other as the Sta them

thought, that the Stars appear of different Bigneſſes, if the Rays which came from the Extremities of them to the Eye of the Spectator, were by that means refracted, ſo as that he ſhould ſee them under a bigger Angle. For modern *Aſtronomers* who have meaſured the Angles under which the Stars appeared, when they were in the Horizon, and when they were at their greateſt Altitude in the ſame Day, [1] have always found them the ſame.

25. That very bright Objects appear larger than they ought to do.

25. It is to be obſerved alſo, that very luminous or bright Objects muſt needs appear bigger than they would do if they were not ſo bright. For if the Image which they impreſs upon the Bottom of the Eye, affects not only a certain Number of Capillaments, but ſpreads it ſelf to the Extremities of other Capillaments which are about it, it is the ſame as if it had covered them alſo; becauſe the Rays have ſo great a Force that all theſe Capillaments are moved by them, and not at all hindred by the Motion of thoſe Rays which come from the other ſurrounding Bodies which affect the ſame Part, but are very faint; therefore a bright Body appears ſo much the bigger, as it takes up part of the Object which is not ſo bright, whoſe Rays are ſwallowed up by it.

26. Why the fixed Stars, when looked at through a Telescope, appear as much diminiſhed, as other Objects appear magnifyed.

26. We may add ſtill further; that the Impreſſion of a very luminous Body may be ſo ſtrong as to extend it ſelf all round to ſome Capillaments, which no Rays at all come to from the luminous Body; in which Caſe, it is manifeſt, that the Object muſt appear much bigger than it would do, if its Light were more faint. And it is certain, that we ſee the fixed Stars in this manner; becauſe if we weaken their Action, by artificially contracting the Pupil, and looking at them through a Hole made in a Card with a Needle, [2] they appear much leſs. But that which moſt ſurprizes thoſe who

themſelves; nay the Stars, when they ſeem to be larger, ſeem alſo to take up more of the Space which ſurrounds them;) though, I ſay, every Part of the Horizon ſeems to be equally inlarged; yet the whole Circle cannot contain any more than 360 Degrees; wherefore Bodies in the Horizon are not ſeen under a greater Angle, but every Degree in the Horizon ſeems greater than in the Meridian.

1. *Have always found them the ſame*) Nay, they have found the Diameter of the Moon, when at the higheſt, a little bigger, than when ſhe riſes or ſets. See *Malbranch's Search after Truth. Book* I. *Chap.* ix. *Sect.* 3.

2. *They appear much leſs*) Nay, that the fixed Stars, by reaſon of their immenſe Diſtance, are but like Points only, except that their Light is a little dilated by Refraction, is evident

who see not the Reason of this, is, that when we look at the Stars with a Telescope, they appear as much diminished as other Objects appear inlarged by it; and for this sole Reason, because hereby the Force of their Rays is very much weakned,

27. *The knowing the Bigness of an Object, helps us much in judgeing of its Distance.*

27. It is certain also, that as the Knowledge of the Distance helps us to find out the Bigness, so likewise the knowing of the Bigness helps us to conceive the Distance. Thus, when we know that a Man is about five or six Foot high, when we see him to appear but very little, we conclude him to be at a great Distance.

28. *How we know the Figure of an Object.*

28. It would be superfluous to show particularly how we know what *Figure* any Object is of, after what has been said concerning knowing the Situation, Distance, and Bigness of its Parts; for the Knowledge of its Figure consists in these.

29. *Why we see an Object single, when we look at it with both Eyes.*

29. Nor is it difficult, after what has been said, to give a Reason why an Object appears sometimes *single* and sometimes *double*: for it is evident, that an Object must appear single, when it so affects the *Sympathetick Capillaments* of the two *Optick* Nerves, as to impress 1 but one Image upon the Brain.

30. *Why an Object appears double.*

30. And this is confirmed from hence, That if we press either of our Eyes with our Finger, so as to make it receive the I[illegible]t on a different Part from what it would do by the common Motion of the Muscles; as it is certain, that the Images which are then impressed on the two Eyes, do not fall upon *the Sympathetick Nerves*, nor reunite in the Brain, so we cannot fail to see the Object double.

31. *Another Way to see an Object double.*

31. So likewise, if we look very intently upon a particular Object, and at the same time another Object be placed nearer or further off, which consequently cannot impress its Image on the *Sympathetick Capillaments* of the two *Optick Nerves*; in this case it must impress two Images on that Part of the Brain which is the immediate

evident from hence, that when they are about to be eclipsed by the Moon; when they enter into its Body, their Light does not decrease gradually (as that of the Planets does) but vanishes all at once, and at the End of the Eclipse, it appears again all at once.

2. *But one Image upon the Brain*) See *the Notes on Chap.* xxxi. *Art.* 20.

Organ

Organ of Vision, and therefore [1] it must be seen double.

32. Having seen how we come to know the Situation, Distance, Magnitude, and Number of Objects by our Sight; nothing more remains but to examine how we know whether they be in *Motion* or at *Rest*. Now it is not difficult to conceive, that we know a Body to be in Motion; first, when its Image appears successively applied to different Images of certain Objects, which we do not compare with any other, but imagine to be immoveable; or when we find that we must turn our Head or our Eyes in order to have the Object always at the End of the Line along which we carry our principal Attention; or lastly, when, if we move neither our Eyes nor our Head, we find it is gone out of that Line. The contrary to all which makes an Object appear to us to be at rest. *32. How we perceive Motion and Rest.*

1. *It must be seen double*) It may be further observed here, that if the Object now mentioned, be placed beyond the Point where the Optical Axes meet, it will then appear double in such a manner, that of the two Images, that which is on the right Hand is seen with the right Eye, and that on the left Hand with the left Eye; but if the Object be on this Side that Point, then the Image which is on the right Hand will be seen with the left Eye; and the Image on the left Hand with the right Eye. The Reason of which is, because in the former Case the Object impresses its Image on HIK the left Side of the right Eye, and therefore is seen by it on the right Hand, and on the EFG, the right Side of the left Eye, and therefore is seen by it on the left Hand; In the latter Case it impresses its Image on KLM the right Side of the right Eye, and therefore appears to it on the Left Hand; and on CDE the left Side of the left Eye, and therefore appears to it on the right Hand. Tab. VII. Fig. 2.

What surprizing Things follow from this Observation, may be seen in *the Notes on the following Chapter*.

CHAP. XXXIII.

Of DIOPTRICKS.

1. That our Opinion about Vision may be confirmed by the Examination of different Sorts of Perspective Glasses and Looking-Glasses.

IN order to prove the Truth of some of those Suppositions which we have made about Vision; we ought now to consider, whether or no all those Things, which upon these Suppositions ought to come to pass, when we look through different Sorts of Perspective-Glasses or upon Looking-Glasses, be agreeable to Experience; for this will be a great Proof of the Truth of these Suppositions.

2. Why an Object is multiplied when looked at thro' a multiplying-Glass.

Tab. VIII.

2. We will begin with Perspective-Glasses, and first let us consider that Sort called *Multiplying-Glasses*, such as that in the Figure ABCD. Now it is evident in the first Place, that without this Glass, the Eye E would see the Object F, by means of the Rays which come from F to G; and because the Superficies BC is here parallel to the Superficies AD, which is opposite to it, and therefore the Refraction which the Rays suffer when they enter into the Glass, is destroyed by the Refraction made at their coming out; it follows, that the Eye ought notwithstanding, to receive the Impression of the Object in the same Place G, where it would have received it if there had been no Glass; and for this Reason it ought still to see the Object in F. It is also certain, that the Object F, would make an Impression upon an Eye placed in N by the Rays which it would send thither, if there were no Glass between; but because these Rays now meet with the Superficies AB, by which they are so refracted, that when they come out of the Glass, they enter into the Pupil of the Eye E, and afterwards go on in such a Manner, as to fall upon that Part of the Bottom of the Eye marked I, where they impress such an Image as an Object placed in M would do; therefore this causes the Eye at the same Time that it sees the Object F in its true Place, to see it also in M. So likewise the Rays which would excite Vision in the Eye, if it were placed in O, and no Perspective-Glass intervened, being in this Case refracted by the Superficies CD, so as to impress an Image of the Object F on the Part of the Eye marked H, where an Object placed

placed in L would make its Impreffion if there were no Glafs; it follows, that the Eye E ought to fee yet another Object F in L. In a Word, it is eafy to infer, that the Eye muft fee the Object F in all thofe Places, where the ftreight Lines terminate, which coming from the Pupil, pafs through the feveral Sides of the Glafs, by which the Rays of the Object are fo refracted as afterwards to make an Impreffion of it upon the *Retina*.

3. Why it fometimes appears colour-ed.

3. I have nothing further to add to this, but only that fometimes the Object when looked at through the Sides AB, CD, may appear differently coloured from what it does when looked at through the Side BC; the Reafon of which is, becaufe the Rays which come from the Object through the Sides AB, CD, are refracted pretty much in the fame manner, as they are by a *Prifm*, which has been explained before.

4. How Rays that come from different Points, are refracted in paffing thro' a convex Glafs. Tab. X.

4. Let us now examine a *convex Glafs* fuch as that in the Figure CDEF. Now it is to be obferved, that as it is the Property of this Glafs to collect into a Point the Rays which fall parallel upon it; fo is it the Property of it, to collect into a Point, likewife the feveral Rays that fall upon it from any fingle Point of an Object, with this Condition, that the Point where they are reunited is fo much the further diftant from the Glafs, as the Point from which the Rays feparate is nearer to it; and this latter Point may be fo near, that the Rays which proceed from it, may never be reunited at all, but become parallel or fomewhat diverging when they come out.

5. How a convex Glafs may make the Image of the Object confufed.

5. This being fuppofed, if the Object AB be at a proper Diftance from the Glafs, all the Rays which come from every Point of this Object, may be reunited again in as many other Points. For inftance, the Rays which come from the Point A may be collected together in H, and thofe which come from the Point B, may be collected together in G. Now if the Eye were placed in the Point I, it is certain, that becaufe the Rays which convey the Image to it from every Point are converging, that is, enter into the Eye with a Tendency to unite together; therefore I fay it muft neceffarily be, fince the Refractions of the three Humours of the Eye are made in the ufual manner, that by means hereof thefe Rays muft unite together fomewhat nearer to the Chryftalline Humour than they would otherwife have done. Wherefore

if this Eye be the Eye of *a young Man*, which cannot flatten it ſelf beyond what is requiſite to ſee Objects diſtinctly, whoſe Rays fall upon it as it were parallel; it is evident, that ſuch a Perſon will ſee Objects ſo much the more confuſedly as the Rays which fall on the Eye have a greater Tendency to unite together more on this Side the *Retina*.

6. How it makes old Men ſee more diſtinct.

6. But if it be the Eye of an *Old Man*, which by the common Decay of Age is become flatter than the Eyes of other Men; becauſe the Reaſon of ſuch a Perſon's ſeeing Objects confuſedly is, that the Rays which come from any Point in an Object are not reunited when they come at the *Retina*, which they fall upon ſooner than they ſhould do, therefore a Convex-Glaſs makes them ſee *diſtinctly*; for it makes the Rays more converging, and ſo helps the Humours of the Eye to reunite them juſt when they come at the *Retina*.

7. Why it makes an Object appear at a greater Diſtance.

7. The *Diſtance* of an Object looked at through ſuch a Glaſs, ought to appear *greater*, becauſe the Diſpoſition of the Rays which come from any Point is ſuch, as cauſes the Eye to put it ſelf into ſuch a Figure as occaſions the Mind to imagine the Diſtance greater. And this is the Reaſon [1] why we think the Object to be further off, if we be not prejudiced before-hand in our Opinion of the Place where it really is.

8. As

1. *Why we think the Object to be further off*) Here the famous Dr. *Barrow* propoſes a very great Difficulty in his *Optical Lectures*, viz. *the* 18. towards the End. *However*, ſays he, *I will not leave off, till I have propoſed to you a very great Difficulty* (*out of the Sincerity I owe to you, and to Truth, by no means to be diſſembled*) *which is contradictory to that Opinion which I have been recommending to you, at leaſt cannot be ſolved by it. It is briefly this. Let the Point A be expoſed to the Lens* Tab. x. *CDEF, at ſuch a Diſtance, that the Rays may be ſo bent as to tend towards uniting ſomewhere in the Axis HD, and let the Point H be the Place where they meet, or the Image of the Point A as we have all along before aſſerted*, viz. the Focus; *between this Point and the Glaſs V, let us ſuppoſe the Eye to be any where placed. I aſk, in what Place ought the Point A to appear to be. In the Nature of Things it cannot be ſeen behind at the Point H* (*becauſe every Impreſſion that affects the Senſe, comes from the oppoſite Part*, viz. *A*) *and it is contrary to Experience alſo. Now it ſeems to follow, from the Doctrine we have laid down, that it ſhould appear to be before us, and at the greateſt Diſtance poſſible* (*a Diſtance exceeding any that we can imagine*). *For the leſs diverging the Rays that come from any Object are, ſo much the further diſtant do we conceive it to be* (*if we be not prejudiced concerning its Diſtance before-hand;*) *and that Object which ſends forth parallel Rays we imagine to be the moſt diſtant that can be. In Reaſon therefore, one would think, that when the Rays come from the Object converging, it ſhould appear, if it were poſſible, at a greater Diſtance yet. But in this Caſe it may be asked in general, what is it that determines the ap-*

parent

8. As to the Situation, that will appear the same as usual, and the same as if we look at the Object without the Glass, because the Eye sees the right Side of the Object

8. Why it makes the Object appear in its true Situation.

parent place of the Point A, and makes it appear sometimes nearer, and sometimes further off, and always in the same Proportion. To which Scruple we can give no Answer from the Analogy of any Thing that has been hitherto said, only that the Point A ought always to appear to be at the greatest Distance. But Experience shows the contrary, viz. *that it appears at different Distances, according to the different Position of the Eye between the Points F and H, and scarce ever (if at all) at a further Distance than the Point A really is; but many times it appears much nearer; nay, the more the Rays which come to the Eye converge, the nearer the Image of the Object approaches. Thus, if the Eye be placed in the Point V, the Point A will seem to be very nearly in its true Place; if the Eye be moved backward to T, the Image will seem to approach nearer; and it will appear still nearer if the Eye be in I or L, and so by degrees till the Eye be placed somewhere near H, where the Object will appear very near, and begin to vanish confusedly. All which seem to contradict our Arguments and Opinions, or at least, do not very well agree with them. And this Experiment not only contradicts our Notion, but all other that I know of, equally. It seems so much to overthrow that antient and common one, which is more a-kin to ours than any other, that the learned* Tacquet *was forced by it to renounce that Principle (upon which alone, almost all his Catoptricks depend) as uncertain, and not to be depended upon, whereby he overthrew his own Doctrine.---In the present Case there is something that lies deep hid in the Subtlety of Nature, which perhaps cannot be discovered, till we understand the Nature of Vision more perfectly. Concerning which, I confess, I have not yet been able to think of any Thing to flatter my self with, much less to give my self entire Satisfaction. I therefore leave this Difficulty with you, and wish you better Success in solving it.* Thus far the famous Dr. *Barrow*.

And indeed it must be acknowledged, that there is a very great Difficulty here. For it is evident, that a Candle, the Rays coming from which, are collected together, and made to converge by a convex Glass, however near, we, by a surprizing Mistake in nur Judgement, conceive it to be, does notwithdanding affect the Eye when it is placed in I or L, exactly in the same manner, as it would do, if those very Rays came indeed from an infinite Distance, as will appear by the following Observations.

First, If the Lens be so broad, that we can see the Candle through it with both Eyes at the same time, though we endeavour all we can to make our Optical Axis diverge to a distant View, yet the Candle will never appear single, but always double; in such a manner double, that of the two Images of the Candle, the right Hand one will appear on the right Hand, and the left Hand one upon the left Hand. Whence it is most manifest, that the Place from whence we ought to judge the Rays come, is beyond that where the optical Axes meet, be it at never so great a Distance; that is, the Candle will affect the Eye in the same manner as if it were at an infinite Distance. See *the Notes on Chap.* xxxii. *Art.* 31.

Neither can it be said here, that the Candle is not therefore seen double, because it is seen, as it were, at an infinite Distance; but that it is only an accidental Thing, and effected by the Interposition of the Glass. For if we look through a concave Glass, it does not appear double; and it may be seen single through a Convex-Glass, if either the Eye or the Candle, be so near the Glass, that the Rays fall upon the Eye, not converging, but only less diverging; in which Case such Glasses are of great Use to render the Sight more distinct.

Object B, by means of the Ray VI, which is on the right Hand of the Ray SI, by means of which, it fees the left Side A.

Secondly, The Reafon of the Appearance of a Candle in this manner when looked at through a convex Glafs, is exactly the fame, as that of a Candle feen erect when the Rays are reflected by a concave Looking-Glafs. In both Cafes the Rays are converging; in both Cafes the Object feems equally near. Now in a concave Glafs, if when the Image is feeo erect behiod the Glafs, a Stick or a long Reed be fo put hetween the Candle and the Superficies of the Glafs as to ftand perpendicular to the Glafs, the Image of that Stick ought to appear of an iofinite Length behind the Glafs (as *Tacquett* has demonftrated in his *Catoptricks, Book* III. *Prop.* 22. aod as the Thing it felf fhows us); and yet the Image of the Candle muft neceffarily appear beyond the Image of this Stick; however near therefore we, through Prejudice, judge the Image of the Candle to be when alone, it is yet evident, that it does really affect the Eye, as if there were an infinite diftance between. And the fame muft be faid of a convex Glafs.

Now bere is the great Difficulty (as the learned Perfon before-mentioned obferved) how it comes to pafs, that when the Rays fall upon the Eye as if they came really from an infinite Diftance, yet the Candle does not feem (as one would expect) to be as remote as poffible, but always very near, though fometimes nearer than other, and that in a certain and conftant Proportion.

Now having confidered this Difficulty on all Sides, I at laft found out the following Solutioo of this furprizing Phænomenon.

Firft, Becaufe we cannot judge of the Diftance of the *Candle* by the meeting of the optical Axis (for in this Cafe, thofe Axis can never meet at all at the Candle, as was before demonftrated;) and becaufe the Judgement which we make of the Diftaoce of Objects by one Eye only, is always the worft aod moft uncertain, and becaufe the true Diftance of the Candle is known before; therefore from Prejudice and Prepoffeffion, it muft always feem to be *pretty near to us*. To which we may add, that we cannot by our Sight perceive any Diftance, how great foever it be, if there be nothing in the intermediate Space: Thus the Body of the Sun, though we very well know, that it is at an immenfe Diftance from us, yet it feems very near; and were it not that we imagine to our felves, from tbe Concavity of the Heavens, a certaio Radius of a Sphere, we fhould think it ftill much nearer. Thus if we look at the Sun through a very long Tube, which hinders our feeing any other Bodies, it feems to be at the End of the Tube.

Secondly, it ought alfo *to appear fometimes nearer than other, and that in a certain and conftant Proportion*. For when the Eye is placed near the Glafs, as in V, the Candle feems further off (as by the Laws of Opticks it ought to do) than it does without the Glafs; now if the Eye be removed backward gradually, the common Refraction of the Rays will be fuch, that the Candle muft neceffarily feem larger and brighter, in the fame Proportion as the Eye recedes from the Glafs. Now this Largenefs and Brightnefs is the Reafon why it feems nearer and almoft clofe to the Eye.

And this is confirmed from hence, that if the Rays of the Candle are firft tranfmitted through a concave Glafs (that the Bignefs and Brightnefs of it may be diminifhed) aod then by paffing through a convex Glafs they be made to converge (as when we look through an inverted Telefcope of two Glaffes) theo we eafily imagine the Caodle to be at a very great, and almoft infinite Diftance.

9. But

9. But this Object will appear *somewhat bigger*, because the Rays VI, SI, as they enter into the Eye, are inclined to each other with a larger Angle, than they are before they were refracted by the Glass, so that they seeming to come from the Places 2 and 3, impress an Image of the Object upon the Eye as big as if they possessed all the Space between 2 and 3. *9. Why it makes the Object appear bigger.*

10. If the Eye be placed in L, the Rays which come to it from any Point are still more converging; and therefore if the Sight were confused before, it will be much more so now. And because the Rays XL, and TL, which come from the two Points A and B of the Object, make a still greater Angle than SI, VI, they must make the Object appear yet bigger. Whence it should seem to follow, that the Vision should not be so clear, but more obscure, because the Rays which impress the Image of the Object on the Eye taking up a larger Space upon the *Retina*, each Capillament of the Optick Nerve receive fewer of them in Proportion: However it is certain, that we can then see as *clearly* as if the Image of the Object were smaller. For there are a greater Number of Rays, which come from every Point and are disposed by the Glass to reunite, that enter into the Pupil when it is so placed as to see the Object very large, than when it is placed where the Object appears smaller. *10. How it may make the Object appear still bigger and more confused.* Tab. X.

11. So likewise if the Eye be placed in Y, the Object ought to appear very *bright* and *clear*, because all the Rays which come from any Point of the Object, and fall upon the whole Superficies of the Glass do then enter into the Pupil; but it must, notwithstanding this, appear *very confused*, because the Rays being already collected together when they are about to enter into the Eye, [1] are refracted afterwards by the several Humours of it, and are by that means dispersed again; so that those which come from the same Point of the Object, impress an Image on a great many of the Capillaments of the *optick* Nerves, upon which the Rays which come from other Neighbouring Points impress their Image also, and this makes the Image of the Object wholly *confused*. *11. How it may make the Object appear wholly confused.*

1. *Are refracted afterwards*) Are dispersed again when they come at the Bottom of the Eye.

12. How it may make the Image appear inverted and confused.

12. If the Eye be placed in M, the Object must neceſſarily appear *inverted*; for we ſee the left Side A by means of the Ray HM which is on the right Side of GM, by which we ſee the right Side of the Object. It muſt alſo neceſſarily appear *confuſed*; as well becauſe the Rays which come from any Point, as A, cannot be exactly collected together at all beyond the Glaſs, ſo that the Eye cannot put it ſelf into any Figure which will reunite all the Rays that come from H; as becauſe when the Rays really come from H as from one Point only, they fall ſo diverging upon the Eye, that it cannot lengthen it ſelf enough to reunite them upon the *Retina*. The Firſt of theſe Two Reaſons ſhows us, that in this Caſe it is impoſſible for the Eye to judge what Diſtance the Object is at; and 1 that it ſeems in that Place in which we before-hand imagine it to be.

13. If

1. *That it ſeems in that Place.*) Here we meet with another Difficulty, concerning the Place in which the Image ought to appear, almoſt as great as the former, which Mr. *Dechales* propoſes in this Manner, *Book* II. *Prop.* 11. *of his Dioptricks. There is,* ſays he, *alway*[illegible] *Difficulty in explaining the Manner how the Eye ſees the Place of the Object, but in this Caſe* Tab. X. *there is a very particular Difficulty, becauſe Reaſon and Experience do not ſeem to agree together, nay, the Experience here is contrary to other Experiments alſo. For it is evident from Experience, that the Object AB is not ſeen in the Place of its Image,* viz. *in GYH, when the Eye is placed in M, for I have tried That a hundred Times, and turned the Glaſſes all Ways in order to find if I could poſſibly make it ſucceed ſo. However, according to Reaſon, it ought without all Doubt to be ſeen in the Place of the Image,* viz. *in GYH. For when the Object AB affects the Eye by the Rays of its Image, it ſhould ſeem as if it ought ſo to affect the Eye as if it were in GYH. For if the Point A, for Inſtance, were in H, it would ſend forth Rays from H to the Eye in M; and though it be in its proper Place* viz. *in the Point A, yet it ſends forth Rays in the ſame Man*[illegible] *as if they came from the Point H; therefore it ſeems as if it ſhould affect the Eye in the ſame Manner as if it were in the Point H.*

To this Difficulty, this famous Perſon anſwers, That the Body AB [illegible] really ſeen by the Eye M in the Place of its Image GYH; but becauſe it can be ſeen only by one Eye at a Time, therefore by a miſtaken Judgement, we imagine it to be further from us. *Thus far He.*

I have oftentimes ſo ordered the Glaſs, that the Object AB (which ought to be a Candle) may be ſeen with both Eyes N and P at the ſame Time. If it be a very large Glaſs the Candle may very eaſily be ſeen with both Eyes at the ſame Time.

Having therefore made exact Obſervation of this Matter through ſuch a Glaſs, I affirm, that the Body AB is ſeen by the Eyes NP exactly in the Place of its Image GYH;

For if the optical Axes Tab. X. be ſo directed, as to meet in the Superficies of the Glaſs, the Candle will always be ſeen double, and in ſuch a Manner double, that the right Hand Image is ſeen by the left Eye, and the left Hand Image by the right Eye. Whence it is moſt manifeſt, that the Image is placed within

13. If the Eye be fuppofed in N, the Second of thefe Reafons will not take Place, and therefore the Object ought to be feen a little more *diftinct*, but always *inverted*, for the Reafon above-mentioned. And as to the Bignefs of it, we judge of that by the Largenefs of the Angle made by the Rays which come from the Extremities of the Object, at their Entrance into the Eye, compared with the Diftance which we imagine it to be at. But it muft not here be omitted, that the Spaces OP and QR, through which the Rays which come from each Extremity of the Object diffufe themfelves, is fo much the greater as it is further diftant from Y, where the Rays which come from every Point of the Object meet. And this makes the Space QP, where the Eye receives the Impreffion of the two Extremities A and B at the fame Time, to be fo much the bigger alfo; fo that there is a large Space for the Eye to move about in, where it will always fee the whole Object.

13. How the Object may appear inverted and less confused.

14. Hitherto we fuppofed the Object to be fo far removed from the convex Glafs, that the Rays coming from it might eafily be reunited in the Bottom of the Eye; let us now fuppofe it fo near the Glafs, that the Rays which come from any one Point of it, have no Tendency towards uniting together, after they are paffed through it, but are only made much lefs diverging than they were before. Let us fuppofe alfo, the Eye to be at fuch a Diftance from the Glafs, that the Refractions which are made at the Entrance into each of the Humours be fuch, as will caufe the Rays which come from any fingle Point of the Object, to unite again in one Point upon the *Retina*; in this Cafe it is evident, that the Vifion muft be *exceedingly diftinct*. For, befides that the Rays which come from different Points of the Object, do not at all confound each other, the whole Image impreffed by them is fo large, that there is a fufficient Number of Capillaments of the Optick Nerve, to caufe the Soul to perceive a great many Particulars, which it would

14. How it may be made to appear very diftinct.

within the Place of Concourfe of the optical Axes, that is, between the Glafs and the Eye, *viz.* in GYH. See *the Notes on Chap.* xxxii. *Art.* 31. But further, if the optical Axes be fo directed as to meet on this Side the Glafs, the Candle will be feen fingle, and manifeftly on this Side the Glafs.

But in the former Cafe, where the optical Axes were directed to a Point further diftant, becaufe the Image of a Candle does not terminate the Sight like a folid Body, and becaufe we were beforehand prejudiced concerning the true Place of it, therefore it feems to be at a greater Diftance.

other-

otherwise have taken no Notice of, if the Image had been so small, that the Rays which came from two adjoining Points of the Object, had been forced to meet together in two different Points of one and the same Capillament.

15. *Concerning Microscopes.* 15. Upon this Foundation it is, that those small Glasses which we call *Microscopes* are made. They consist of [1] one Glass only, which is so convex, that if a Flea, or any other small Object be placed at about an Inch Distance from the Eye, and the Glass be put between them, it will cause the Rays which come from any single Point of such a small Object, and which diverge very much, to diverge afterwards so little, that the ordinary Refractions of the Humours of the Eye, will determine them to unite in one Point on the *Retina*. By this Means the Eye which without a Glass cannot see any Object distinctly which is nearer than a Foot Distance from it, may be made to see one which is twelve Times nearer it. From whence it follows, that the Diameter of the Image which this Object impresses upon the *Retina* is twelve times larger, and consequently, that the whole Superficies is a Hundred aud Forty Four times as large, as it would be, if the Object were at a Foot Distance; wherefore since it extends it self upon a Hundred and Forty Four times as many Capillaments of the Optick Nerve as it would otherwise do, the Object cannot but be seen very distinctly.

16. *How a concave Glass refracts the Rays which come from different Points of an Object.* Tab. XI. 16. Let us now examine a *concave Glass*, such as that in the Figure CDEFGH, the Property of which is, according to what was before said, to make the Rays which it receives from any single Point of an Object, to become more diverging than they were before they passed through the Glass. Thus the Rays which come from the Point A, and fall upon that Part of the Glass marked VX, spread themselves after they are passed through it, from R to Z; and those which come from the Point B, and fall upon the same Space VX, extend themselves through the Space YT. Further, it is also the Property of a concave Glass, so to incline the Rays, which come from two different

1. *They consist of one Glass only.*) There are some which consist of several Glasses, that are much more nice. What, and how surprizing Things have been found out by the Help of these *Microscopes*, may be seen in Mr. *Hook's Micrography*, and in others.

Points

Points of the Object, to each other; that when they meet together, they make a leſs Angle than they would do, if they had not paſſed through ſuch a Glaſs. For inſtance, the Ray MI, which comes from the Extremity of the Object A, and the Ray LI, which comes from the other Extremity B, make ſo ſmall an Angle, *viz.* MIL, that they ſeem to come from the Places marked N, O.

17. Whence it follows, that if the Eye be placed in I, and look upon the Object AB, it will ſee it *confuſedly*: Becauſe the Rays which come from every Point, are ſo diverging, that the Refractions of the Humours of the Eye cannot make them unite in ſo many Points upon the *Retina*. *17. How it may make the Viſion confuſed.*

18. However, there may be ſome Eyes ſo much longer and more gibbous than ordinary, as to reunite the Rays which they receive from any ſingle Point of a diſtant Object, before they come to the *Retina*, ſo that they can ſee only near Objects diſtinctly; They therefore who have ſuch Sort of Eyes as theſe, may make good uſe of a concave Glaſs to ſee diſtant Objects diſtinctly with; becauſe by this Means the Rays which come from any ſingle Point of the Object are made ſo diverging, that the large Refractions made by the Humours of ſuch Eyes, do not reunite them before they come at the *Retina*. *18. That it may make ſome Perſons ſee very diſtinctly.*

19. If an Eye of the ordinary Figure be placed at a greater Diſtance from the Glaſs, as at P, it will ſee *ſomewhat more diſtinctly*, becauſe the Rays which fall upon the Pupil from any ſingle Point of the Object are leſs diverging than they were in I; and on the other Hand, an Eye too long or too gibbous will ſee it ſo much the more confuſedly as the Point P is further from the Glaſs, becauſe the Rays which come from any ſingle Point of the Object, being leſs diverging, the Refractions made in the Eye, determine them to meet before they come to the *Retina*. *19. How it may ſometimes make the Sight leſs and ſometimes more confuſed.*

20. But whatſoever the Figure of our Eyes be, whether they are fitted to ſee Objects that are near, or ſuch as are at a Diſtance; whoever makes uſe of ſuch a Glaſs will ſee the Object in its true *Situation*; for the Rays which cauſe us to ſee the right Side of the Object, come to us from the right Side; and thoſe which cauſe us to ſee the left Side, come from the left Side. *20. That it ſhews the Object in its true Situation.*

21. As

21. That it makes it appear nearer to us. 21. As to the *Distance*, it makes that seem *less* than it really is, because when the Rays which come from any one Point, enter into the Humours of the Eye, they diverge just as much as they would do, if they did indeed come from a Point of an Object much nearer.

22. That it makes it appear less. 22. And as to the *Bigness*; because the Extremities of the Object are seen by Rays which make a less Angle than they would make without a Glass, it follows, that it must appear *much less*.

23. That it makes it look equally clear. 23. Because the Rays which come from any Point of the Object are made more diverging by passing through a concave Glass, it follows, that fewer of them can enter into the Pupil, than if they had not passed through the Glass; however the Vision ought not to be the less clear upon this Account; because this is made good by the Image being impressed on a less Space of the *Retina*, so that every Capillament of the *Optick* Nerve is sufficiently shaked to cause us, when we look through such a Glass, to see the Object as *clear* as when we look on it without a Glass.

24. That it makes a large Space for the Object to be seen in. 24. To what has been hitherto said concerning the concave Glass, we may add, that the Space RT, which contains the Rays that come from the two Extremities of the Object, being very large, it follows, that the Eye may see the Object entire in any Part of this large Space.

25. Concerning Telescopes. 25. One of the best Inventions of our Age, is that of *Telescopes*. For by the Help of them we have not only discovered some Particulars in the Stars, which were not observed before, but they show us also a Multitude of new Stars in the Heavens, which we cannot see without them, nor should we ever have come to the Knowledge of them otherwise. They were indeed first discovered by Chance; but the Invention appeared so surprizing, and so useful, that the greatest Genius's have laboured hard to bring them to the highest Perfection possible. I cannot therefore forbear explaining the Nature of them in this Place; and the so doing will very much confirm all that has been hitherto said about Vision. They consist commonly of two Glasses, fixed to each End of a Tube: That Glass which is at the End next the Object, and is for that Reason called the *Object Glass*, is a little convex, and the other Glass which is

is at the End of the Tube next the Eye, and is therefore called the *Eye-Glaſs*, is on the other Hand, very [1] concave, that is, much thinner in the Middle, than at the extreme Parts.

26. The *Object-Glaſs* cauſes all the Rays which come from every ſingle Point of the Object, to unite together very nearly in as many different Points, on a Superficies which we are to ſuppoſe on this Side the Glaſs, at a greater or leſs Diſtance from it, according as the Glaſs is more or leſs convex ; now becauſe the Rays which come from different Points of the Object, croſs one another as they paſs through the Glaſs, it is eaſy to conceive, that they paint ſuch a Sort of an Image upon this Superficies as we have before ſhown they do upon the *Retina*, and that it is ſo much the larger, as the reuniting of the Rays cauſes it to be at a greater Diſtance from the Glaſs: If therefore the Bottom of the Eye were put in the Place of this Superficies, and it were poſſible for the Humours of it not to make any Refractions; we ſhould have a very large Image impreſſed on the *Retina*, by Means of this ſingle Glaſs, and it would fall upon ſo great a Number of the ſmall Capillaments of the Optick Nerve, which would receive diſtinctly, the Impreſſion of every ſmall Part of the Object, that it would be impoſſible but that the Viſion muſt be very diſtinct. *26. The Property of the Object-Glaſs.*

27. But becauſe the Humours of the Eye cannot be hindred from cauſing the uſual Refractions, they muſt neceſſarily ſo refract the Rays which come from every Point of the Object, and which had before a Tendency to unite together, that they will unite before they come at the *Retina*, and then ſeparating again, will impreſs a confuſed Image upon that Tunick. Now the *Eye-Glaſs* is ſo fitly placed between the *Object-Glaſs* and the Place where it would make the Rays meet; that it cauſes thoſe which come from any Point of the Object converging, to become parallel, or rather a little diverging; but yet it does not hinder the Rays which come from different Points, from being as much diſperſed as they were when they croſſed each other in paſſing through the Object-Glaſs. And thus the Refractions neceſſarily made by the *27. The Property of the Eye-Glaſs.*

1. *Concave*) There are alſo Teleſcopes conſiſting of two, three, or four convex Glaſſes ; Concerning which, ſee *Regis Phyſicks, Book* VIII. *Part*. II. *Chap*. xxxix, xl, xli.

Humours of the Eye, instead of being injurious, as they were without this Glass, become very useful with it; for they unite those Rays which this Eye-Glass dispersed; and by this Means the Image which the Object impresses on the *Retina* becomes perfectly distinct, and at the same Time very large. Whence it follows, that the Object is seen distinctly and [1] so much the bigger as the Rays which come from any one of these Points, are less diverging, and make us think it at a greater Distance.

28. *Why these Glasses, the longer they are, make the Sight so much the more obscure.* 28. The best Curvature that can be of the Superficies of Glasses for Telescopes, is, [2] that of an *Hyperbola*, or any such like Figure, and not the Curvature of a *Sphere*. But Workmen have not yet been able to make their

1. *So much the bigger as the Rays which come from any one of these Points are less diverging, and make us think it at a greater Distance.*) That is, by how much the Rays of every Pencil being less dispersed, make it appear further off. For the further the Object seems to be from us, the more do we necessarily imagine the Pencils of Rays, which cross one another as they pass thro' the Object Glass, to divaricate, that is, the Object seems so much the bigger.

2. *That of an Hyperbola, or any such like Figure,* &c.) *Cartes* took a great deal of Pains about these sort of Figures, and about the manner of polishing Glasses, but with no great Success. For it is evident, that *Spherical* Glasses, as they can be more easily and more accurately made, than Elliptical or Hyperbolical ones; so are they to be preferred before such upon this Account, because they do more exactly refract the Pencils of Rays which are out of the Axis of the Glass. And indeed, it is not to be ascribed to the Unfitness of the Figures of the Glasses, but to quite other Causes, that Telescopes cannot be made absolutely perfect and compleat. The Two Principal of which Causes are these.

First, The unequal Refraction of the Rays themselves; (*See the Notes on Chap.* xxvii. *Art.* 52.) by which means neither the *Eye-Glass* (which is Convex) can be made a Sphere small enough to magnify the Object; nor the *Object-Glass* of a sufficient Aperture, to render the Object bright and distinct, but every Thing will immediately be tinged with Colours, and confounded by the unequal Refraction of the Rays. For the eminent Sir *Isaac Newton* has shown, that the Difference between the Refraction of the least and most refrangible Rays, is about the Twenty seventh Part of the whole Refraction of the mean refrangible Rays; and that the Focus of the most refrangible Rays is nearer to the *Object-Glass* than the Focus of the least refrangible ones by about a Twenty seventh Part and a Half of the whole Distance between the *Object-Glass* and the Focus of the mean refrangible Rays. (Opt. p. 74.) And therefore the greatest Errours which arise from *the spherical Figure of the Glass*, are very much less than the Errours which arise from the unequal Refraction of the Rays themselves; nay, in some Cases, the Proportion is as great between them, as 1200 to 1 (pag. 89.) From whence it abun-

their Glaſſes of any other Curvature but that of a Sphere, of which they take ſo ſmall a Part, that it does not ſenſibly differ from an *Hyperbola*. But then there is this Inconvenience attends it, that there does not fall ſo many Rays upon it from any one Point of the Object, as there would do if the Glaſs were larger; and conſequently all the Rays which come from the whole Object, and which ſpread themſelves upon a large Portion of the *Retina*, ſhake but a very few of the Capillaments of the *Optick* Nerve; and this is the Reaſon why we ſee Things more obſcurely, than when we do not uſe ſuch a Glaſs; and the longer ſuch Glaſs is, and the fewer the Rays are which come upon the Pupil from any Point of the Object, ſo much the weaker and more obſcure muſt that Object appear.

abundantly appears, that not *the ſpherical Figure of the Glaſſes*, but the different Refrangibility of the Rays themſelves, is the Cauſe why Teleſcopes have not hitherto been made abſolutely perfect and compleat, and that there can be no Remedy for this Inconvenience by any way figuring or poliſhing *refracting Glaſſes*; this excellent Perſon, at length invented, and agreeable to Experiments, propoſed the manner of making a Teleſcope which could cauſe the Object to be ſeen by *Reflexion*: Concerning the Conſtruction and Uſe of which Inſtrument, See Optic. pag. 95.

Secondly, *If the Theory of making Teleſcopes could at length be fully brought into Practice, yet there would be certain Bounds, beyond which Teleſcopes could not perform.* For the Air *through which we look upon the Stars, is in* a perpetual Tremor; *as may be ſeen by the tremulous Motion of Shadows caſt from high Towers, and by the twinkling of the fixed Stars. But theſe Stars do not twinkle when viewed through Teleſcopes which have larger Apertures. For the Rays of Light which paſs through diverſe Parts of the Aperture tremble each of them apart, and by means of their various, and ſometimes contrary Tremors, fall at one and the ſame Time upon different Points in the Bottom of the Eye, and their trembling Motions are too quick and confuſed to be perceived ſeverally. And all theſe illuminated Points conſtitute one broad lucid Point, compoſed of thoſe many trembling Points confuſedly and inſenſibly mixed with one another by very ſhort and ſwift Tremors, and thereby cauſe the Star to appear broader than it is, and without any Trembling of the Whole. Long Teleſcopes may cauſe Objects to appear brighter and larger than ſhort ones can do, but they cannot be ſo formed as to take away that Confuſion of the Rays which ariſes from the Tremors of the Atmoſphere. The only Remedy is a moſt ſerene and quiet Air, ſuch as may perhaps be found on the Tops of the higheſt Mountains above the groſſer Clouds.* Newt. Opticks, p. 98.

CHAP.

CHAP. XXXIV.

Of Looking-Glasses.

1. Of the different Sorts of Looking-Glasses. BESIDES plain Looking-Glasses, which are every where used, there are two other Sorts, *viz.* Convex and Concave ones, not to mention those which are compounded of these three Sorts, which are capable of being infinitely diversify'd.

2. The common Property of all Sorts of Looking-Glasses. 2. Each Sort of Looking-Glasses has indeed its particular Property or Manner of representing the Object; but in this they all agree, that they so reflect the Rays of Light, that the Angle of *Incidence* is equal to the Angle of *Reflexion*, and that the reflected Ray is not in the least turned aside, either to the right Hand or to the Left; that is to say, 1 the incident and reflected Rays are always in the same Plane which is perpendicular to the Superficies of the Glass; whence it follows, that though the visible Object sends forth from every Point a Multitude of Rays which are reflected by the whole Superficies of the Glass, yet a determinate Number of them only can come to the Eye when it is fixed in a certain Place.

1. *The incident and reflected Rays are always in the same Plane which is perpendicular to the Superficies of the Glass.*) This Property wonderfully perplexed the famous Dr. *Barrow*; *you will not easily find any good and clear Account of this Matter amongst the Writers of Opticks; almost every Thing that they alledge with relation to it, is either begging the first Principle, or else labours under some incomprehensible Obscurity; nor do I much wonder that this should be the Case of those who always consider a Ray of Light as one continued streight Line; which if granted, I can scarce believe it possible to assign any good Reason for this Thing. I therefore think that a Ray of Light is not a mere Line, but a Body endued with all the Dimensions; so that it may be cylindrical or prismatical,* &c. *Lect.* I. *Sect.* 11. But there do not seem to be any necessity of recurring to the Figure of the Rays; it is all one whether they be cylindrical or prismatical, whether they be solid Bodies or indivisible Lines. Tab. II. Fig. 6.

For let GBL be the Superficies of the Earth (which I suppose to be plain and smooth) A the North, I the South, AB a Ray of Light. Now it is evident, that this Ray of Light is carried with a double Determination, the one AG downwards to the Earth, the other AH directly to the South; the first Determination is resisted by the Superficies of the Earth, the other is not; the Ray therefore ought to go on directly to the South with this Determination, that is, in a Plane perpendicular to the Superficies of the Earth; nor can it turn towards the East in an oblique Plane.

3. This

3. This being supposed, let AB be a plain Looking-Glass, by Means of which the Eye C sees the Object DE; having drawn from any Point at Pleasure, suppose D, the Line DIL perpendicular to the Superficies of the Glass, we shall show that this Point D ought to be seen in the Point L of this Perpendicular, so that the Distance IL, which we imagine it to be at behind the Glass, shall be equal to the Line ID; [1] for it is easy to demonstrate, that the Rays DF, DG, by which the Point D affect the Sense, are so reflected in the Lines FC, GH, that they enter into the Pupil CH, as if they really came from the Point L: so that this diverging of the Rays causes the Eye to put it self into such a Shape, as gives occasion to the Soul to imagine that it sees the Object really in the Point L.

3. How a plain Looking-Glass makes any one Point in the Object to be seen. Tab. VII. Fig. 3.

4. And as the Point D was taken at pleasure, what has been said concerning that, ought equally to be understood of all other Points of the Object; and therefore it is evident, that when we look upon an Object in a plain Looking-Glass, *the whole Image ought to appear as far behind the Glass, as the Object is placed before it.*

4. That the whole Object ought to appear as far beyond a plain Looking-Glass as it is placed on this Side of it.

5. It is further evident, that this Object ought also to appear of the same Bigness, as if it were really placed in LM: For the Space which the Image seems to take up, is comprehended between two parallel Lines which are at the same distance from each other as the Extremities of the Object are.

5. That a plain Looking-Glass ought to make the Object appear of its true Bigness.

6. Lastly, This Object ought so to appear in the Looking-Glass, that the upper Part should be seen above, and the right Side on the right Side, and so of the rest. Thus the Part D, which is higher than E being seen by the Rays of Incidence DF, DG, and by the reflected Rays FC, GH, which seem to come from the Point L; and the lower Part E being seen by the Rays of Incidence EN, EO, and by the reflected Rays NC, OH;

6. That it ought to appear in its true Situation. Tab. VII. Fig. 3.

1. *For it is easy to demonstrate,* &c.) For the Angle DFI = to the Angle CFB; and the Angle CFB = to the Angle IFL, therefore the Angle DFI = to the Angle IFL; and the Angles at I are right, and the Side IF common. Therefore the Triangles DFI and IFL are similar and equal. In like manner the Triangles DGI and IGL are similar and equal, Therefore the Triangles DGF and FGL are similar and equal. Q. E. D.

Tab. VII. Fig. 3.

T which

which feem to come from the Point M; we refer the Senfation which we have of the Point D to the Place L, and that which we have of the Point E to the Place M, which is lower than L.

7. That it is the fame Thing whether we look upon the Glafs with one Eye or with both.

7. What has been faid concerning one Eye, ought equally to be underftood of the other. And indeed if we fuppofe the Spectator principally attentive to look upon the Point L, it will eafily appear, that his two Optical Axes, will be fo inclined to each other, that they will feem to meet in the Point L. Whence it follows, that the Rays which come from every Point of the Object to enter into one of the Eyes, feem to come from the fame Points beyond the Glafs, from whence the Rays feem to come which caufe every Point of the Object to be feen by the other Eye.

8. That a convex Looking-Glafs ought to make the Object appear at a lefs Diftance behind the Glafs,than it is on this Side. Tab. IX. Fig. 1.

8. As to a *convex Looking-Glafs*, fuch as that in the Figure reprefented by ABC, by Means of which the Eye D fees the Object EF; [1] it is eafy to apprehend, that it fo reflects the Rays which fall upon it from any Point of the Object, fuch as EB, EG, that the reflected Rays BD, GH diverge juft as much as if they really came from the Point I, which is at a much lefs Diftance behind the Glafs than the Object is before it: And this is the Reafon why we fee the Image much nearer than when we look upon a plain Looking-Glafs.

9. That it ought to appear fmaller.

9. Further, the Point L from whence the Rays MD, NH, feem to come, by which we fee the Point F, [2] is fo near the Point I, that IL appears much lefs than EF, that is, a convex Looking-Glafs makes the Object appear much lefs than it really is.

10. That it ought to appear in its true Situation.

10. But though in *this* a convex and plain Looking-Glafs differ from each other, yet they agree in another Particular, *viz.* that they both make the Object to be feen *in its true Situation*, as appears from hence, that

1. *It is eafy to apprehend,* &c.) This may eafily be demonftrated, if we draw a ftraight Line BG reprefenting a plain Looking-Glafs, and compare it (as to the Situation) with the Tangents of the Points B and G. (Tab. IX. Fig. 1.)

2. *Is fo near the Point I,*) There are two Reafons of this. Firft, Becaufe the Image in this Glafs, by reafon the Rays of every Pencil are more difperfed, is not fo far diftant from the Vertex of the *Angle of Vifion* as in a plain Looking-Glafs. Secondly, Becaufe this *Angle of Vifion* is therefore lefs, becaufe the Portion of the Glafs upon which the Rays that are reflected to the Eye, fall, is lefs than in a plain Looking-Glafs.

the

the Rays EBD, EGH, by which the Eye sees the Point E are higher than the Rays FMD, FNH, by which it sees the Point F, which is the lower Part of it.

11. As to Vision made in looking upon a concave Looking-Glass, it may be diversify'd several Ways according as the Eye and the Object are in different Positions. Let us suppose a concave spherical Looking-Glass, whose Center is about the Point T; and let us imagine in the first Place, that by Means thereof the Eye D sees the Object EF which is pretty near the Superficies of it. This being supposed, the Rays EB, EG which come from the Point E, are so reflected to the Pupil, that BD, GK diverge but very little, and seem to come from the Point H, which is at a much greater distance beyond the Glass, than the Object is on this Side of it. [1] And this makes us refer the Image of it to a greater distance than if we look on a plain Looking-Glass, and to a still greater than when we look on a convex Looking-Glass.

11. Why a concave Looking-Glass makes the Object appear at a greater distance behind it, than it is at before it. Tab. IX. Fig. 2.

12. As to the Rays which come from different Points of the Object, they are in this Case so reflected, that those which affect the Sense from the upper Part of the Object, are higher than those which affect the Sense from the lower Part of it; thus the Rays BD, GK, which cause the Sensation of the Point E, are higher than the Rays ID, LK, which cause the Sensation of the Point F; and these Rays ID, LK, seeming when they enter into the Pupil as if they came from the Point M, are the Cause of seeing the Point F as if it were in M. And because HM is much bigger than EF, it follows that the Object ought not only to appear in its *true Situation*, but also *much bigger* than it really is.

12. How it may make the Image to appear in the same Situation and much larger than the Object. Tab. IX. Fig. 2.

13. The Rays EN, FO, as they go towards the Glass divide more and more from each other; wherefore if they be continued backwards, they must meet together somewhere in the Point P, and afterwards dividing again that which was uppermost, will be lowermost, and that which was lowermost will be uppermost; whence we cannot but conclude, that if an Object be in QR,

13. How it may make the Image appear inverted. Tab. IX. Fig. 2.

1. *And this makes us refer the Image*, &c.) See the *Notes on Chap.* xxxiii. *Art.* 7. for the Case of the concave Looking-Glass here is the same as that of the convex Glass there.

 it

it muſt appear *inverted*; but becauſe the Rays which ought to affect the Senſe from any ſingle Point of it, fall in ſuch a manner upon the Superficies of the Glaſs that as they are reflected to the Eye, they croſs one another in ſeveral Places between the Glaſs and the Eye; and ſo cannot be re-united in one Point upon the *Retina*, therefore the Viſion muſt be very confuſed.

14. How it may be that the Pupil only can be ſeen.

14. If the Eye be placed exactly in the Center of a concave Looking-Glaſs, it can ſee nothing but the Pupil; for thoſe Rays only which fall perpendicularly on the ſpherical Superficies, are reflected to the Center; and thoſe Rays only which come from the Center fall perpendicularly upon the Superficies; wherefore the Rays which go from the Pupil and fall upon the whole Superficies of the Glaſs, return from thence to the Eye again, which muſt therefore ſee the Pupil ſpread all over the Glaſs.

15. How the Object may appear very large. Tab. IX, Fig. 2.

15. If the Object EF continues in its Place, and the Eye be moved to X, between the Rays BD, GK, prolonged; it is evident, that it will ſtill ſee the Point E by means of ſome of thoſe Rays which it ſaw it by before; but it will not ſee the Point F, by Means of the Rays ID, LK, which came to it from the Part IL of the Looking-Glaſs; inſtead of which, thoſe which fall from F upon Y, and go from thence to X, will make the Point F to be ſeen, and conſequently it will ſeem to be ſomewhere in Z, and ſo the Object will appear as large as HZ.

16. How it may appear abſolutely confuſed.

16. If the Eye continues in D, and the Object EF be removed backward to P, the Rays which come from every Point of it, and fall upon any Part of the Glaſs as BG, will be leſs diverging than they were before. Wherefore after Reflexion they will become converging, and more diſpoſed to unite when they enter into the Eye, than they ordinary are, and ſo muſt really unite before they come at the *Retina*, which will make the Viſion *confuſed*. But it will be ſtill *more confuſed* if the Eye be in that Place where the Rays which come from every Point of the Object meet together again; for theſe Rays at their Entrance into the Eye will begin to be [1] ſeparated

1. *Separated by Refraction*) They are ſeparated, not by Refraction, but merely by receding from the Point where they croſs each other.

parated by Refraction, and will be separated more and more by the Humours of it.

17. If the Object remain in P, and the Eye be removed a little from the Place where the Rays which come from every Point of the Object reunite, the Rays when they enter into the Pupil, will diverge too much; wherefore because the Eye cannot lengthen it self enough, the Object will *appear confused* here also.

17. Another Reason of its appearing confused.

18. But if the Eye be moved so far backward from that Place where the Rays reunite, that the Rays which enter into it, be not too much diverging, the Vision ought then to be *distinct*; and what is here very remarkable, and the most surprizing Effect of a concave Looking-Glass, is this; that because we are accustomed to refer our Sensation to the Place from whence the Rays which affect the Eye from every Point of the Object seem to come, therefore *the Image must appear between the Glass and the Eye*; so that if a drawn Sword be presented before the Glass, we shall see the Blade come out from the Glass, and grow longer and longer as we approach nearer to it; because the Rays which come from every Point of the Object, the nearer it is, are the less inclined to each other after Reflexion, and therefore meet together at so much the greater Distance. [1]

18. How the Object may be seen between the Eye and the concave Looking-Glass.

19. It

1. The Phænomena of a concave Looking-Glass, may be very properly reduced to five Cases.

First, Let *the Arrow or the Candle EF be near the Glass*. Now because the Pencils EBGKD, FILKD do not cross each other, wheresoever the Eye be placed, whether it be near or at a distance; therefore the Image HM ought always to appear erect. And because the Rays of those Pencils are reflected, not converging to each other, but only less diverging, therefore the Candle ought to appear to be at a certain Distance beyond the Glass.

Tab. IX. Fig. 2.

Secondly, Let *the Candle be in the very Center T*. Theo because all the Rays fall perpendicularly upon the Glass, they must necessarily be all reflected to the Center it self; therefore whereever the Eye is placed, out of the Center or any of the Lines tending to the Center, it is evident, that it cannot see the Candle at all in the Glass.

Tab. IX. Fig. 2.

Thirdly, Let *the Eye be in the Center T*. Then because no Rays but those which fall perpendicularly are reflected to the Ceoter: therefore the Eye can see nothing but its own Image spread all over the Glass.

Fourthly, Let *the Candle QR be further distant from the Glass, and the Eye KD further distant also*. Then because the Pencils QO, RN, cross each other, it is evident, that

19. That Objects do not paint their Images on the Superficies of Looking-Glasses.

19. It may be observed here, that they have been very much mistaken, who have affirmed, *that visible Objects paint their Images upon the Superficies of Looking-Glasses*; for every Thing there is so confused, that there is no one Part of the Glass but receives Rays from all Parts of the Object at the same Time; and indeed it is certain that all Objects which we see by the Help of a Looking-Glass, do not impress their Image any where else but on the Bottom of the Eye, unless when we see them by Means of a concave Looking-Glass, under the Circumstances mentioned in the foregoing Articles; and in that Case it is certain, that the Image impressed by

the Image of the Candle ought to appear inverted to the Eye KD. And because the Rays of every Pencil are reflected converging, and after meeting somewhere in a Focus, go from thence diverging to the Eye; therefore the Image will not appear beyond the Glass, but on this Side of it, in that Focus. So likewise, *in another Figure*, because the Pencils GD, BC cross each other, it is evident, that the Image of the Candle GB ought to appear inverted to the Eye in Q; and also on this Side the Glass, and not beyond it; because the Rays of every Pencil cross one another in a Focus, as was before explained. But why in this Case we should not imagine it to be very near, (unless we look *very intently* upon it) when it is really very near, See *the Notes on Chap.* xxxiii. *Art.* 12. for the Case is the same here as in the Perspective Glass there.

Tab. IX. Fig. 2.

Tab. XVII. Fig. 3.

Fifthly, Let *the Candle GB be at some Distance from the Glass, and the Eye M very near it*. Then because the Candle GB is seen by other Pencils GHM, BCM which do not cross each other; it is manifest, that the Image of GB ought to appear erect again, but more confused.

Tab. XVII. Fig. 3.

But in this Case it is particularly to be observed, that the Eye M hath no way to judge either in what Place, or at what Distance behind the Glass the Image of the Candle ought to appear; for since the Rays of every Pencil converge towards each other, that is, do not come from any given Point, but as it were from an infinite Distance, to enter into the Eye; and since those reflected Rays BM, CM do not meet with their respective Perpendiculars of Incidence DΓ, FL, (from which meeting the Place of the Image is always determined) there remains nothing to judge of the Distance of the Image by but mere Prejudice.

Tab. XVII. Fig. 5.

It was very ill therefore in * *Tacquet*, after he had so well demonstrated under this *Head*; *that the reflected Image in any Looking-Glass is always seen in the Place where the reflected Rays meet with their Cathetus of Incidence*, (*the Cathetus of Incidence* is a Line drawn from any Point in the Object perpendicular to the Glass) to except this last Case as contradicting this Axiom; whereas it is no ways contradictory to it. For when the Eye is in such a Position, as to receive the reflected Rays before they meet with their Catheti of Incidence, the Image cannot be seen where they meet, because they don't meet any where; neither is it seen in any other certain Place; but it affects the Eye as if it came from an infinite Distance; in the same Manner as when the Rays come converging out of a Perspective Glass. *See the Notes on Chap.* xxxiii. *Art.* 7.

* Catropticks Book III. Prop. 30.

the Object, is not upon the Superficies of the Glass, but in the Air, in the Place where we imagine we see the Object, and where the Rays which come from every Part of it, are united after Reflexion. [1]

1. Besides such Looking-Glasses where we look upon one Superficies only, we may also consider Perspective-Glasses, or certain clear Glasses, as Looking-Glasses consisting of two Superficies; according to the Variety of which, there is also a wonderful Variety of reflected Images. For not only the first Superficies which receives the incident Rays out of Air, but also the second Superficies which receives the Rays going out of Glass into Air, exhibits a reflected Image, as may be seen by placing a Candle before such a Glass.

First then, let a Candle be placed before a Glass which is plain on both Sides; then the Images reflected by each Superficies, will both be seen erect and exactly like each other, excepting only, that That which is reflected by the farther Superficies will seem a little more obscure, because a great many of the Rays have already been reflected by the first Superficies.

Secondly, Let the Glass be plain on the one Side, and convex on the other; then if the Candle be placed before the convex Superficies, the Image will be reflected erect by each Superficies (unless the Glass be of such a Thickness, and the Fore-side of it so convex, that the Rays in passing through it are made converging, and after having been reflected by the plain Superficies, and passing a second Time through the convex Side, meet in a Focus before they come to the Eye; in which Case the Image from the latter plain Superficies will be seen inverted) but that which is from the first and convex Superficies, will appear less. But if the Candle be placed before the plain Superficies, then the Image reflected from the first Superficies will be erect again, and that from the further Superficies, which is concave within, will be reflected inverted, and will also seem to be much nearer to the Eye, than that from the first and plain Superficies.

Thirdly, Let the Glass be plain on one Side, and concave on the other. Then if the Candle be placed before the concave Superficies, the Image reflected from the first Superficies will be inverted, and that from the further one, erect. But if the Candle be placed before the plain Superficies, the Images reflected from each Superficies will be erect, but that from the further one, which is convex within, will appear less.

Fourthly, Let the Glass be concave on one Side, and convex on the other. Then if the Candle be placed before the concave Superficies, the Images by each Superficies, will be inverted; but if before the convex Side, they will be both erect.

Fifthly, Let the Glass be convex on both Sides. Then the Image of the Candle placed before it, will always be reflected erect by the first Superficies; and always invert by the other Superficies, which is concave within.

Lastly, Let the Glass be concave on both Sides. Then the Image of the Candle placed before it, will always be reflected by the first Superficies inverted, and always erect by the latter which is convex within.

CHAP. XXXV.

A Solution of some Problems concerning Vision.

1. *Of the Rays which we see dart upwards and downwards from a Candle.*

THOUGH I have been very large upon this Subject of Vision, yet I doubt not but that I have passed over a great many curious Questions, the Solution of which may perhaps be somewhat difficult to those who are not well acquainted with our manner of Explication. That this Treatise therefore may be as little defective as possible, and to show the Usefulness of it, I shall here propose some of these Sort of Queries; and leave the Excellency, at least the *Truth* of our Hypothesis to be judged of, by seeing how easy it is to resolve them. And First, I ask; *Whence is it, that when we look upon a lighted Candle at a little Distance with our Eyes winking, there seem to come Rays of Light from the Flame of the Candle, and dart upwards and downwards into the Air? And whence is it also, that if an opake Body be put between the Eye and the Place where we see the uppermost Rays, we still continue to see them, and on the contrary, cease to see the lowermost Rays?* In order to understand the Reason of these Phænomena, let us consider the Eye A, the Eye-lids of which H, I, are so near each other, that there is only a very narrow Passage left, through which the Rays which come from the Candle BCD pass to impress its Image on the Part of the *Retina* EFG in the Manner above explained: Further, it is to be observed, that the Parts H and I (which are used to touch one another when the Eye is close shut,) are so smooth, that they resemble [1] two small convex Looking-Glasses, which reflect the Rays of Light falling upon them, to-

Tab. IX. Fig. 3.

1. *Two small convex Looking-Glasses*) The Rays in this Case, are not reflected by the inward Superficies of the Eye-lids themselves, in the manner of Looking-Glasses, but are refracted by the Humour which sticks to the out-side of them; in explaining all the rest of this Phænomenon, the Reason is the same.

wards the *Retina*, to the Parts of it EK, FL, which otherwise would not have been affected but by Objects which are about BM and CN. Wherefore the Impression made upon EK cause the Appearance of bright Rays, which we refer to the Place BM, and the Impression made on GL cause the Appearance of the Rays which we imagine to be in CN. But that which is most worthy of Observation here, is, that the Part of the Flame B, which illuminates the lower Eye-lid I by Rays which are reflected to the upper Part of the *Retina* LG, cause the Appearance of the lower Rays CN; wherefore if an opake Body OP be put between the Eye and upper Part of the Flame, we shall cease to see the lower Rays, and continue to see the upper ones, because they are seen by Means of the Rays CH, which come from the Bottom of the Flame, and which are not intercepted. And all the Difference that we shall find in these upper Rays, is this; that whereas before they seemed to be in BM, they will now seem to be on this Side the opake Body OP. But when the Eye is open as usual, that is, when the Eye-lids come no nearer than S and T, we ought not to see these Rays of Light; because the Rays which fall upon those Places which we now compared to Looking-Glasses, enter but a little Way into the *aqueous Humour* at furthest, and are hindred from going any further by the *Uveous Tunick*.

2. *Whence is it that when a Fire-brand is turned round, we see a Circle of Fire through which it passed?* The Reason of this, is, because the Fire-brand makes a circular Impression upon the *Retina*, and the Motion of it being very quick, some of the Impression made at first remains till it returns again. *2. Of a Fire-brand turned round.*

3. From this Phænomenon we may draw this Conclusion, that though Vision is made in an Instant, it does however continue some short Space of Time. *3. That the Sense of Seeing continues some time.*

4. *Whence is it that a Cannon-Ball, or any other black Body, passing very quick before a white Wall, cannot be perceived at all?* The Reason is, because a black Body making no Impression upon the Eye; the Ball interrupts the Rays of Light reflected from the Wall, so very little, that the Motion which these Rays excited in the Eye just before, is continued in it for so short a Time. *4. Why we cannot at all see some Bodies which move very quick.*

5. *Why*

5. Why some Persons can see Objects distinctly, at a certain Distance only.

5. *Why do some Persons see distinctly at a certain Distance only, and see confusedly at a greater or lesser Distance?* It is [1] because they are so accustomed to look at that Distance, that the Muscles by which the Figure of the Eye is altered, are grown stiff, and uncapable of performing their Office; in the same Manner as the other Muscles of the Body are uncapable of moving the Members of it, if they have not been exercised for a long Time. To which we may add; that the Tunicks which contain the three Humours of the Eye, are so hardened, that they will not so easily yield as before.

6. Of Vision thro' a Hole made with a Needle.

6. *Whence is it that an Object which appears confused, when we look at it too near, may be seen very distinctly at the same Distance through a Hole made with a Needle in a fine Card, or a Piece of Paper?* The Reason is, because the Eye then receiving a less Quantity of Rays from every Point of the Object, each of them paints its Image but upon a very small Space, so that they which come from two neighbouring Points, do not confound each other's Actions. [2]

7. *Whence*

1. *Because they are so accustomed, &c.*) This often happens to some particular Sort of Workmen, as Engravers, *&c.* and ought to be look'd upon as a particular Sort of Distemper.

2. It may also here be enquired; *Why a very small opake Body suspended in the Middle of an Hole between the Eye and a great many Lights, is multiplied so, as to be seen before every Light?* The Reason is, because the Rays cross one another in that Hole, and are intercepted by the small opake Body. Let us imagine GHILN to be the Eye, PEDFQ the small Hole in the Paper, HD the small opake Body suspended in the Middle of the Hole; and A, B, C, three Candles. This being supposed, the Body HD will intercept the Ray BO; then the Shadow of that Body will fall on O, and therefore the Body it self will be seen in B; so likewise it will intercept the Ray AX; so that its Shadow will fall upon X, and therefore it will be seen in A. Lastly, it will also intercept the Ray CY, whose Shadow will fall on Y, and therefore it will be seen in C. Neither is it necessary that an opake Body should be suspended in a Hole at all: For since the Rays that come from a great many lucid Bodies, cross one another in the *Tunica Cornea*, if you fix your Eyes upon a Fire of burning Coals, and put a very slender Iron-rod close to your Eye, it will be greatly multiplied, and seen as it were before every Coal.

Tab. VI.

Secondly, *Why an Object is seen double when looked at with one Eye through two Holes made in a Paper close to each other?* In order to account for this Effect, it is to be observed, that the Objects are never seen double, but when all the Rays of the same Pencil, meet together before they come to the Bottom of the Eye, or after they are passed beyond it. In order to have these Rays meet together before

7. *Whence is it that those who have been couched for Cataracts, can see but confusedly afterwards, and why do they want very large convex Glasses in order to see distinctly?* Before we resolve this Question, it is to be observed, that a Cataract is not a Pearly Substance formed between the Aqueous and Chrystalline Humours, as has been long imagined, but is an Alteration made in the Chrystalline Humour it self, which has thereby intirely lost its Transparency and is become opake, if not through the whole Substance of it, yet at least in some Part of it; which may very easily be, for this Humour is composed of a great many Membranes one upon another, which become visible when it is boiled. Whence

7. Why they who have been couched of Cataracts want large magnifying-Glasses.

fore they arrive at the Bottom of the Eye, let us suppose CDE to be the Pupil of a young deep Eye, the middle Part of which D is covered by the small Interstice between the Holes of the Paper; and let OQNPR be the Bottom of the Eye. Now because this opake Body intercepts a great many of the Rays, and for that Reason makes all the Pencils hollow, that is, without any Rays in the Middle of them; it is evident that the Point A is seen in the Place marked 2 by the extreme Rays HR, and a few others near them, and in the Place marked 3 by the Rays HQ, HN, whereas, otherwise it would have been seen only confusedly in A by the middle Rays P, and those which surround them. And because the same Thing happens in every other Point of the Arrow, it shows that it ought so to appear double, that when the right Hole DE of the opake Body which covers the Pupil is stopped, the left Image OQ, and the Arrow on the right Side disappear; and if the left Hole be stopped, the right Image and left Arrow disappear. But if on the other Hand, we suppose the Eye to be old and flat, so that the Bottom of it is not OQNPR, but very near GYH, and that the Rays of every Pencil arrive at the Bottom of the Eye before they are collected into a Point, the Arrow will be seen double again, but so that the Images of it upon stopping the Holes by Turns, will disappear in the contrary Manner to what they did before. Further, by the same Argument we may collect, that if there be a great many Holes instead of Two, there ought to be a great many Images of the Object seen. Lastly, Why the Body which appears double in this Manner, appears to be edged with Colours also, may be seen in the *Notes on Chap.* xxvii. *Art. 65. towards the End.*

Tab. X.

Thirdly, *Why, if there be two Candles A and B so placed, that through the Hole S, only the Candle A can be seen with the right Eye F, and only the Candle B with the left Eye D; when both the Eyes are open together, is there one Candle only seen, as if it were in H; but the Candles must be both of the same Heighth, and at the same Time no opake Bodies must be seen with which the true Places of the Candles A and B may be compared?* The Reason hereof, is, That because one Candle only can be seen by each Eye; and one Eye only makes a very bad Judgement of the true Distance of Objects; each of these Candles are therefore seen nearer than it really is, the one in the Line AF, and the other in the Line BD, and therefore they seem both to unite in the common Place H as if they were but one.

Tab. XVIII. Fig. 4.

it follows, that when the Cataract is taken away, the whole Chrystalline Humour is taken away, or at least, is made flatter or less convex than it was before: Now if this Humour be less convex than it was before, the Rays which the Eye receives from every Point of the Object will not be so much refracted, or will not incline so much to each other, as to be able to unite together when they come at the *Retina*; and this must make the Vision confused. But this may be remedied by the Help of a very convex Glass, which makes the Rays that were before diverging, become converging when they enter into the Eye.

8. Why we see confusedly, when we are under Water.

8. *Why do Divers, when they are under Water, see all Things confusedly, unless they make use of very convex Glasses?* The Reason is, because the Rays of Light which come to them from the Object, are very little refracted in passing out of Water into the Aqueous Humour of the Eye, so that those Rays which come from the same Point, are not united together when they fall upon the *Retina*; and this is remedied by very convex Glasses.

9. Why if we look intently with one Eye upon a small Object, we cannot see another small Object which is very near it.

9. *Lastly, Whence is it, that if we shut one Eye, and look intently with the other, upon a small Object, which is at six Foot Distance suppose; we cannot at the same Time see another small Object, which is at a little more than half a Foot Distance from it; though we can see it, if it be a little nearer, or a little further off?* The Reason is, because when this other small Object is at the Place where it cannot be seen, it impresses the Image exactly on that Part of the Bottom of the Eye where the *Optick* Nerve enters in, and where the Separation of the Capillaments of this Nerve is made, in order to spread themselves every Way, and cover the Bottom of the Eye; so that this Image has no Effect, because it does not fall upon the Extremities of the Capillaments of the *Optick* Nerve, which is necessary in order to Sight, as has been before explained.

10. That it is sometimes worth while to take the Pains to find out the Truth.

10. There are innumerable other Questions upon this Subject that might be asked; but they who rightly understand the *Nature of Vision*, will find it no great Difficulty to resolve themselves, and the Pains which they take in finding out the Solution of them, will make them have a clearer Notion of them, and render them more familiar: And as to those who are unca-

pable

pable of underſtanding them, or who will not be at any Pains; it is to no purpoſe to attempt to ſatisfy them, by explaining a great Number of Queſtions. Wherefore I ſhall here conclude this firſt Part; which is ſufficient to content all reaſonable Perſons, and to open the Minds of ſuch, that they may for the future proceed in a right Method of diſcovering the Truth, and avoiding Error, which are the Two Things we ought principally to have in View in all humane Sciences. For the Exactneſs and Improvement of Reaſon, together with ſuch a Freedom and Openeſs of Mind, as may render it capable of judging ſincerely and impartially, and of clearing it ſelf of all Difficulties, are incomparably more to be valued than the Knowledge of all the Sciences in the World.

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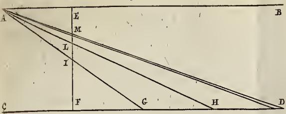

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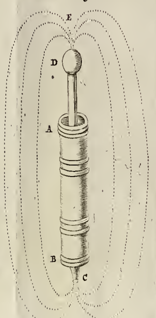

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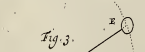

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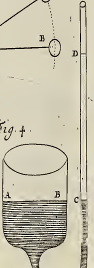

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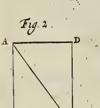

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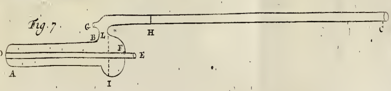

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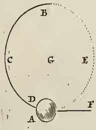

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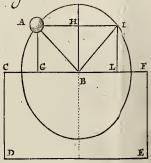

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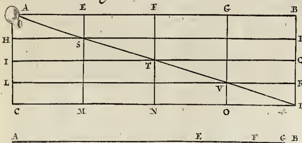

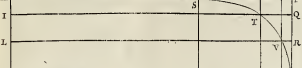

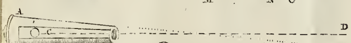

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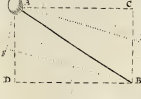

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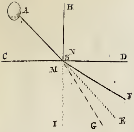

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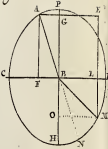

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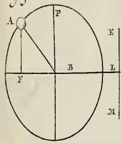

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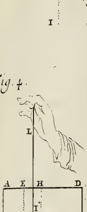

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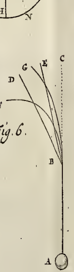

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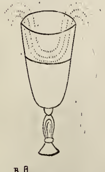

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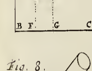

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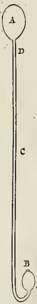

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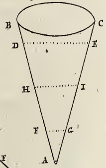

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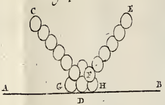

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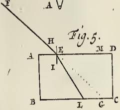

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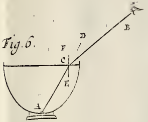

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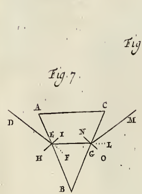

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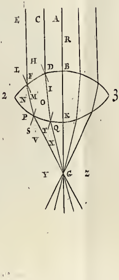

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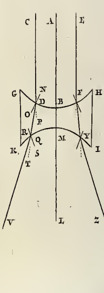

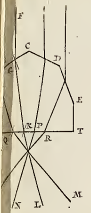

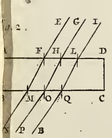

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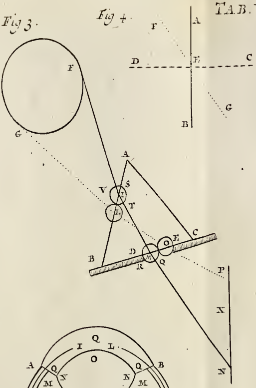

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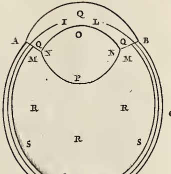

Fig. 5.

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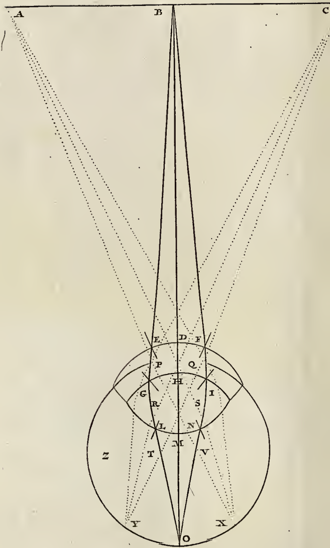

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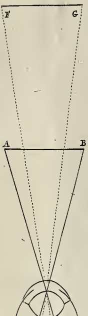
Fig. 1.



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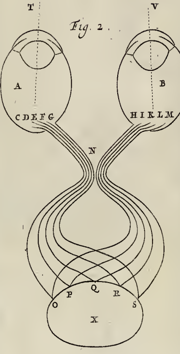

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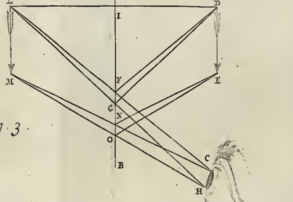
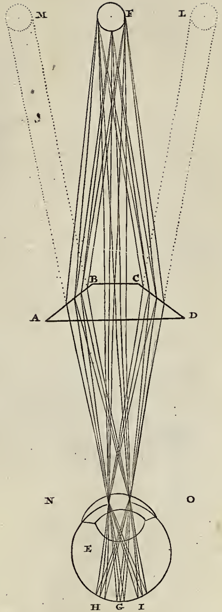


. VIII .



TAB. IX.

Fig 1.

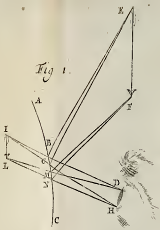


Fig 3

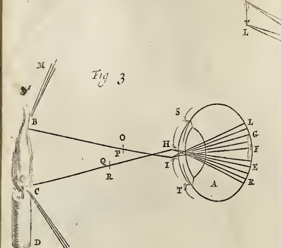
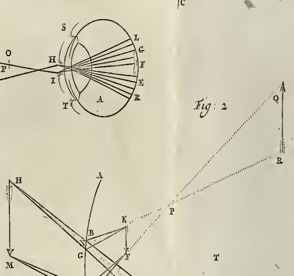


Fig: 2



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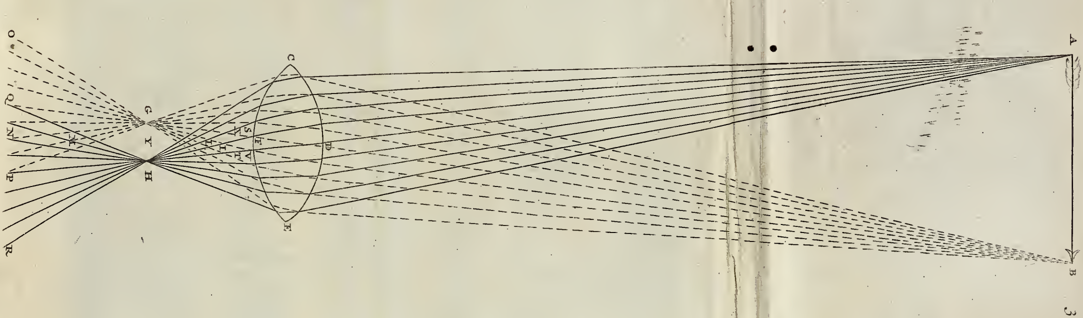

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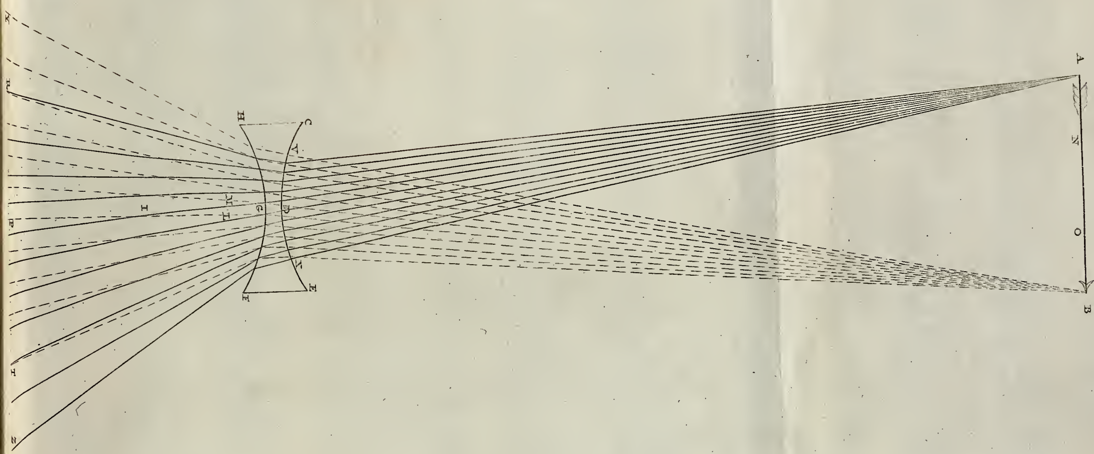

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